TEXTILE RESEARCH JOURNAL

VOL. XV, NO. 9 September, 1945

Mechanical Properties of Textiles, I

George Halsey,* Howard J. White, Jr.,* and Henry Eyring **

Contribution of the Textile Foundation and Princeton University, Frick Chemical Laboratory, Princeton, New Jersey

I. Introduction

In the study of the mechanical properties of a textile the authors' aim is to use the language of molecular structure, thereby suggesting possible beneficial modifications in the preparation or processing of the fiber. The mechanical properties are particularly useful because these properties are notably more quantitative than any others, such as feel, or luster, or other elusive properties which are dependent on sense perception. At the same time the mechanical behavior is often one of the more important qualities of a textile and seldom, if ever, fails to assume great importance at one time or another, if only for a moment in the process of manufacture.

In the case of a synthetic fiber, it is always the concern of the chemist to understand the effect of the process on the end product because his task is often to produce a certain type of fiber for a specified purpose. In the case of a natural fiber the problem is quite similar, with the difference that it is the chemist's task to preserve what he has initially against the vigorous processes of modification and preparation for use. And since, even in the case of rayon, from raw source to product there is a continuous loss in degree of polymerization, the chemist fights a losing battle. Only in the case of a true synthetic, such as nylon, which is polymerized by the chemist, does he actually "improve" the molecule to any degree.

In the approach to the problem of the tensile properties of textiles the effort is always made to devise a scheme for classifying and evaluating the various textiles. In the specification of a simple spring a single constant is needed. For mechanical purposes, two springs with the same elastic constant are interchangeable. Under certain circumstances the same simplicity holds for a fiber.

In a given testing machine, under fixed conditions the determination of the breaking load gives a number that adequately describes a fiber in the operation of that machine. Fibers with the same "modulus" would give identical results on this machine. However, there would be no reason to expect that two such "identical" fibers would behave in any predictable manner on a new machine, unless the nature of both machines and both fibers had been studied.

Under such a heterogeneous process a given fiber would yield a long series of "moduli" as varied and as critical as the intelligence of the engineer in charge would permit. Unless, however, these experiments were analyzed on the basis of an integrated theory, the behavior of a fiber on the

* Fellows of the Textile Research Institute.
** Acting Director of Research, the Textile Foundation.

newest machine would be predicted at best by a more or less adequate statistical treatment of previous results. To secure a basis in theory, therefore, it is necessary to recognize in a class of test results of greater or less inclusiveness the presence of a unifying assortment of physical concepts or elements and explain the behavior accordingly.

II. The Linear Model*

In general, in the theory of plastic-elastic solids it has been customary to consider these solids as being dependent on linear differential equations of the type [1]

$$a\ddot{q}_i + b\dot{q}_i + cq_i = Q_i$$

where q is a generalized displacement from equilibrium and Q represents external forces; a is an inertia term, on the acceleration $\ddot{q}$, which is not considered to be important here; c is a potential term, determining the action of the spring, while b is a viscosity associated with $\dot{q}$, the velocity, and represents energy dissipation, as it is on an odd function of time.

The qualitative evidence for a law of this type is widespread. A yarn has elastic properties; it stretches and returns to shape. On the other hand, the yarn will yield, it will creep, it will take time to return to shape. And the integral of force times the distance shows a loss in energy over a round trip—a hysteresis loop. There is always loss of energy unless the movement is very fast or very slow. If it is very fast, the dissipative system cannot move. If it is very slow, no force can accumulate on the viscous element, so again there is no loss. Thus the loss is largest at an intermediate rate of elongation. This is explained adequately by the qualitative concepts of viscosity and elasticity. In addition, the viscous resistance appears to vanish with the velocity, which is of very great importance in simplifying the mathematical treatment.

Aside from satisfying the qualitative considerations outlined above, a linear differential equation presupposes several stringent limitations. This is a consequence of its linear nature in q. Essentially it assumes Hookean elasticity and Newtonian viscosity. These assumptions will be discussed separately.

A. Hooke's Law

Hooke's law forms the basis of the mathematical theory of elasticity. Love's treatise on that subject [1], for example, discusses the validity of this law in a complete manner. It was discovered by Hooke in 1660. It states that there is a simple proportionality of strain to stress. Love comments that it was published in 1678 [2] and previously in 1676, in the form of an anagram.

In discussing the evidence for or against Hooke's law it must be observed that all of the deviations noted by Love are dissipative ones, and thus need to be explained by the viscous element. These hysteresis loops may be analyzed on the basis of the following scheme:

If the force of viscous resistance, φ, is an odd function of $\dot{q}$ alone and the force, S, at the "spring" is a function of position only, then the equation of motion becomes, for one degree of freedom,

$$S + \varphi = Q$$

where Q is the external force.

Now, if the conditions of the experiment are made so that the velocity at q on the way out is equal to the velocity at q on the way in, then the

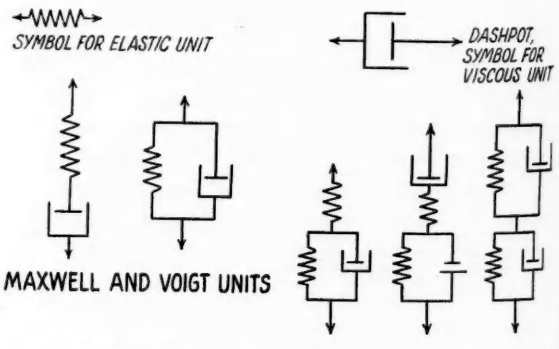

FIG. 1. *Some possible arrangements of viscous and elastic elements to correspond to various behaviors.*

*TABLE OF NOTATION:

a—shape factor for relaxation
f—force/cm² acting on a viscous element
F—total force/cm² acting on a fiber
$\Delta F^{\ddagger}$—activation free energy
h—Planck's constant
k'—specific rate constant
k—Boltzmann's constant. 6.6×10^{27} erg. sec.
l—elongation per unit length
q_i—a generalized displacement from equilibrium
Q_i—external force on a mechanical system
t—time
T—temperature
V_m—$\lambda_1\lambda_2\lambda_3$—volume of a flowing segment
V_f—$\lambda_2\lambda_3\lambda$—volume of flow hole
α—$\frac{V_f}{2kT}$
β—$\frac{\rho}{K}$, shape factor for elongation experiments
ρ—rate of elongation $=\frac{dl}{dt}$
λ_1, λ_2, λ_3, λ—dimensions of flow
φ—αF
τ—$K\alpha\beta t$

mean of the corresponding values of Q is the value of S. By considerations similar to this on a three-element model to be discussed later, a Hookean behavior in a rayon under study was observed by the authors up to about 0.8 of the breaking strength. In this case, however, even this deviation was probably due to another viscous element brought into play as breaking was beginning. Experiments at a slow rate of elongation to avoid viscous losses, yet fast enough to avoid permanent creep, are under way. They show an apparent Hookean behavior.

The acceptance of Hooke's law is a temporary expedient, supported by direct experiment, and with the knowledge that a treatment such as is necessary for rubber yields it as an approximation only. Such an approximation is useful only when other parts of the theory are undergoing refinement, and must necessarily be replaced when a detailed molecular theory becomes usable.

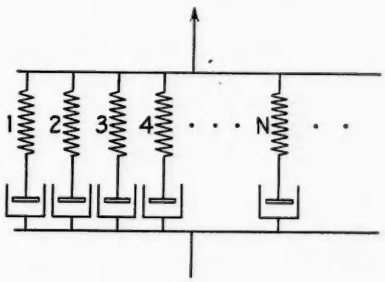

FIG. 2. *Arrangment of elements that leads to Wiechert's distribution.*

B. The Newtonian Viscous Element

A complete treatment of classical viscous resistance is presented by Lamb in *Hydrodynamics* [1], Chapter XI.

There is no theoretical basis for the Newtonian viscous law, except as a limiting law, explained below, outside of the kinetic theory of gases. However, in the experiments of Hagen and Poiseuille [3] and subsequent more accurate experiments, all based on the rate of flow through tubes, the existence of a viscosity independent of velocity is very well established [4].

On the other hand, striking deviations in the flow of materials under very high forces are established beyond doubt [5]. The range of rates of distortion over which the Newtonian law holds was, however, found to be very large, and Lamb states: "We can hardly hesitate to accept the equation in question as a complete statement of the laws of viscosity."

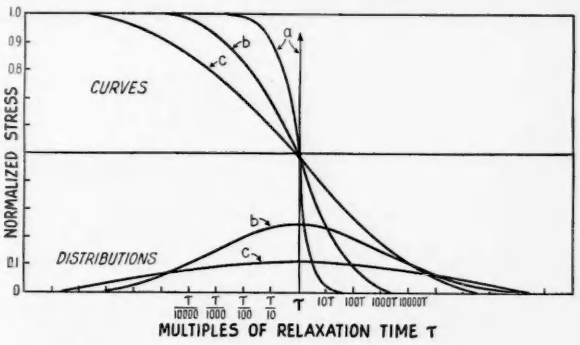

FIG. 3. *Wiechert relaxation curves with their corresponding distributions. A distribution of relaxation time provides one possible means of prolonging relaxation over several powers of ten in the time in agreement with experiment.*

C. Linear Arrangements

With the Newtonian viscous law supposedly firmly established for liquids, and the Hookean law established for many solids, the problem of arranging these elements arises. The two elements, dashpots and springs, are conceived of as being joined in various ways, as indicated in Figure 1. It should be noted that when an arrangement is made of a few elements, such as one of the examples in Figure 1, it is intended to represent the fiber as being made up of many such arrangements, working in a similar manner. The validity of this procedure can be justified only on the basis of the results, which are usually adequate. Since the solid has an enormous number of degrees of freedom, the only proper treatment would be a carefully established distribution of elements. Because of the difficulty of determining the constants, very involved models are troublesome. At the same time, the data are seldom accurate enough to distinguish between two models that differ very little. As a result, enough elements are introduced to account for the qualitative behavior and the resulting network is adjusted to fit as well as possible.

1. The Wiechert Model. Many efforts are made to fit creep or relaxation data with a single viscosity, with poor results. The first efforts to fit such data more accurately led to the concept of a multiplicity of relaxation times distributed more or less sharply (see Figure 2).

Wiechert [6] proposed the special distribution of a normal error function. As shown in Figure 3, this leads to a spreading out of the relaxation process over a wider range of time as the distribu-

tion of viscosity is broadened. Curve *a* is the relaxation curve for a single viscosity shown for comparison. The Wiechert theory is adequate to fit many substances in creep, although an unsymmetricalness remains that cannot be fitted. This will later be interpreted as non-Newtonian behavior.

2. Other Distributions. A general distribution might be expected to fit any data, and it probably would, but the difficulty much outweighs the empty triumph of explaining something with an infinite series of constants, particularly if no physical basis for the distribution is given.

3. General Discussion. At this point it is pertinent to remark that no matter how successful one may be at "fitting data" with the old linear equations, the molar constants that are obtained are meaningless in terms of molecular structure, and thus are of no help at all to the chemist. The effort is made here to analyze the data of stress-strain properties with a view of correlating these properties with such molecular constants as the volumes of the flow unit and of a molecule, and the activation energy for flow.

III. Models Based on Chemico-Kinetic Theory

A. Kinetic Interpretation of the Spring

1. Rubber. The kinetic interpretation of the elasticity of high polymers has been developed largely with the elasticity of rubber in mind.

The nature of the rubber molecule is such that the following simplifying considerations are employed.

(*a*) The elongation of rubber is isovoluminal. This has been established experimentally, and is a logical consequence of the near-liquid nature of rubber, with its phenomenally low elastic constant [7].

(*b*) The elongation of rubber is not accompanied by any internal energy change, so that the elasticity of rubber is an entropy effect due to the fewer configurations available in a stretched state. This is also a consequence of the loose liquid structure of rubber, whereby no strain of valences is caused by the rearrangements during extension.

(*c*) The elongation does not reach the stage at which the chain is stretched straight. This condition, although manifestly violated in large extensions, is assumed to allow the use of the limiting distribution of molecule length for infinite chain length, which is a simple Gaussian distribution.

By more or less straightforward processes, it is possible to arrive at an expression of the following form:

$$\text{tension} \propto \frac{l}{l_0} - \left(\frac{l_0}{l}\right)^2$$

where l is the stretched length and l_0 the initial length.

The constant of proportionality can be given more or less significance, and in the most simplified case:

$$\text{tension} = (3kTN)\frac{l}{l_0}$$

for small elongations.

N is interpreted to be the number of links between tie-ups of chains per cubic centimeter, but at best it is a rather indefinite concept.

2. Crystalline Solids. In the case of an elastic solid of the crystalline type the assumptions made above may be categorically denied. The question of the elastic constant depends on the shape of the potentials for the atoms or molecular units, and the configuration is reasonably constant. The calculation of the elasticity is conceptually as easy as the quantum mechanics of the molecule in question. For a rigid solid, the elastic constant is dependent only on potential and is, therefore, really independent of the temperature.

3. Textile Fibers. The case of a textile fiber is

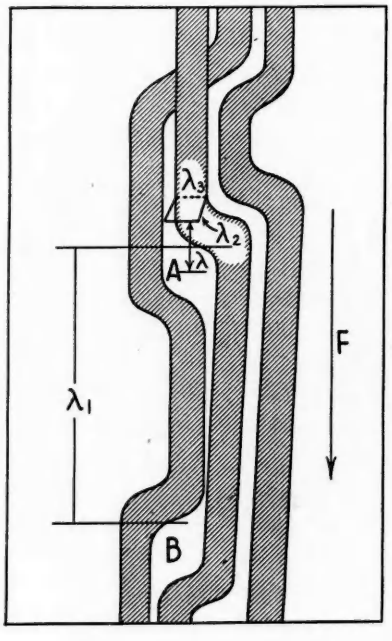

FIG. 4. *Simplified representation indicating voids or holes into which segments of molecules can jump, thus relaxing stress.*

intermediate between the two extremes, and hence more difficult than either. Because of the large elongations (of the order of 10 percent) some rearrangement necessarily takes place in textiles, but it is not true that this rearrangement takes place without increase in potential energy.

An increase in temperature acts to weaken the elastic constant, notably in the case of ramie [8]. This is the opposite of the effect one would observe with an entropy spring and is not explainable by a pure potential spring, which would have no temperature dependence.

The effect is doubtless to be explained by a change in structure analogous to a glass-like softening over an extended temperature range. If one chooses to speak in terms of the rubber theory, the rise in temperature decreases the number N of cross bonds. This same situation arises with rubber as it is heated from the low-temperature crystalline form up to ordinary temperatures.

It is the authors' hope to treat this problem quantitatively in a later paper.

B. Non-Newtonian Viscosity

Change of shape in fibers involves flow units exchanging old neighbors for new ones. Even when no forces are acting the same processes are going on. These processes are unbalanced and accelerated by putting stresses on the fiber. Molecules cannot move into the space occupied by other molecules. As a result, all movements take place at loose or empty places in the structure. Such points are indicated at A and B of Figure 4

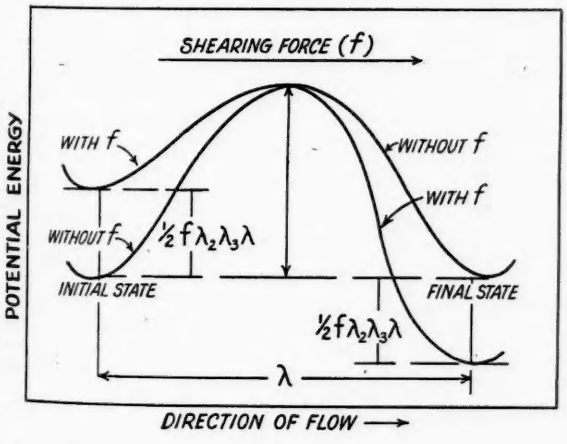

FIG. 5. *Diagram indicating how an applied stress alters the potential energy barrier a flowing molecular segment must surmount as it flows from one equilibrium position to the next.*

and on the average are assumed to occur at intervals of λ_1 in the direction along which the force is acting. If the pull on a square centimeter of surface is f, then on a single flow unit the force acting will be $f\lambda_2\lambda_3$, where $\lambda_2\lambda_3$ is the effective cross-sectional area of the flow unit normal to the direction of flow. Actually, if a particular unit pulls with difficulty, the force will concentrate on this unit as it lags behind, thus acting to maintain its velocity. However, $f\lambda_2\lambda_3$ will be the effective force acting to speed up the flow units. Now, even if no force were acting, the segment just above A may be supposed to move downward k' times per second and upward an equal number of times. The force $f\lambda_2\lambda_3$ acts through a distance λ doing an amount of work $f\lambda_2\lambda_3\lambda$. The unit, in moving forward, presumably will go through an intermediate state of higher energy at the distance $\lambda/2$. This assumes a symmetrical potential barrier. Thus the applied stress only contributes the work $f(\lambda_2\lambda_3\lambda/2)$ toward surmounting the barrier. If the flow-unit moves against the applied force, it will have to do this same amount of work against the applied stress (see Figure 5).

As a result, the flow unit now moves in the forward direction $k' \exp\{f\lambda_2\lambda_3\lambda/2kT\}$ times per second and in the backward direction

$$k' \exp\{-f\lambda_2\lambda_3\lambda/2kT\}$$

times per second. The net number of times any flow unit moves forward per second thus equals

$$k'[\exp\{f\lambda_2\lambda_3\lambda/2kT\} - \exp\{-f\lambda_2\lambda_3\lambda/2kT\}].$$

The forward velocity of a flow unit is the net number of times it moves forward times the distance, λ, it jumps—that is,

$$\lambda k'[\exp\{f\lambda_2\lambda_3\lambda/2kT\} - \exp\{-f\lambda_2\lambda_3\lambda/2kT\}].$$

The resulting rate of strain is obtained by dividing this velocity by the distance, λ_1, where, as stated previously, λ_1 is the distance in the flow direction between points of flow. This gives for $\dot{S}$, the relative change in length of fiber per second due to flow:

$$\dot{S} = \frac{\lambda}{\lambda_1} k' 2 \sinh \frac{f\lambda_2\lambda_3\lambda}{2kT}.$$

This relaxation theory of flow has been applied extensively to viscosity and plasticity [9] and to the behavior of rubber [10].

Now the volume of the hole swept out by the

motion is $V_h = \lambda_2\lambda_3\lambda$, and the volume of the flowing segment (or molecule) is $V_m = \lambda_1\lambda_2\lambda_3$, so that the rate of flow can be written

$$\dot{S}_1 = \frac{V_h}{V_m} k' \, 2 \sinh \frac{V_h f}{2kT}.$$

Now by the statistical thermodynamic theory of reaction rates [9]

$$k' = \frac{kT}{h} e^{-\Delta F^{\ddagger}/RT}$$

so the rate becomes

$$\dot{S}_1 = 2 \frac{V_h}{V_m} \frac{kT}{h} e^{-\Delta F^{\ddagger}/RT} \sinh \frac{f V_h}{2kT}.$$

Now if $V_h f \ll kT$, the rate reduces to

$$\dot{S}_1 = \frac{V_h^2}{h V_m} e^{-\Delta F^{\ddagger}/RT} f,$$

the traditional linear relationship, because

$$\sinh x \approx x$$

when $x \ll 1$ (when $x \gg 1$, $\sinh x = e^x/2$).

Thus, the viscosity is shown to be a function of: (1) a universal frequency kT/h dependent on the temperature; (2) V_h the volume of the flow "hole"; (3) V_m the segment or molecular volume; (4) $\Delta F^{\ddagger}$, the free energy of activation; (5) the temperature. (1), (3), and (5) are known, and (2) and (4) are evaluated, from the data.

It is shown that, depending on the size of $V_h f/2kT$, the behavior will be Newtonian ($V_h f/2kT < 1$) or exponential ($V_h f/2kT > ca\ 3$), and that both behaviors are explained and connected by a hyperbolic sine law.

IV. Three-Element Non-Newtonian Model

A complete treatment of a particular case follows, to serve as an example for further discussion.

A. The Stress-Strain Relationship in a Rayon Fiber

The stress-strain relationship in a rayon fiber shows that a simple elastic element does not suffice to duplicate the behavior of such a fiber. That an open Hookean element is present, however, is shown by the immediate response in a linear manner to elongation of the fiber. Hysteresis is present, necessitating a viscous element. This viscous element is not present in an open state. (By an open viscous element is meant one not restrained by a restoring spring.) This is true because total relaxation of stress at constant strain is not found for the duration of the experiment. The arrangement indicated by this qualitative analysis is shown in Figure 6. A complete qualitative description would require a very stiff open viscous element to account for permanent set. The following discussion applies to that part of the deformation not showing permanent set. For the purposes of this discussion the viscous resistance is considered to follow a hyperbolic sine law with the springs Hookean. The validity of these assignments is thus under investigation.

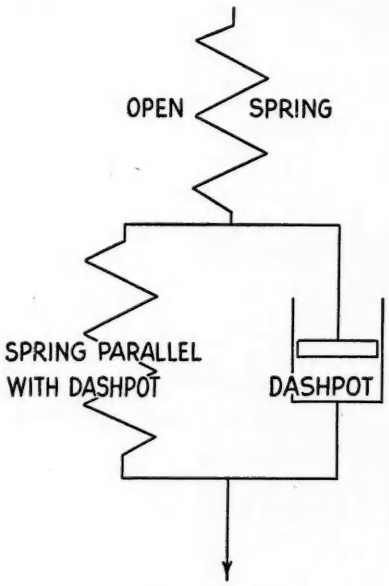

FIG. 6. *Three-element model here used to describe the behavior of fibers.*

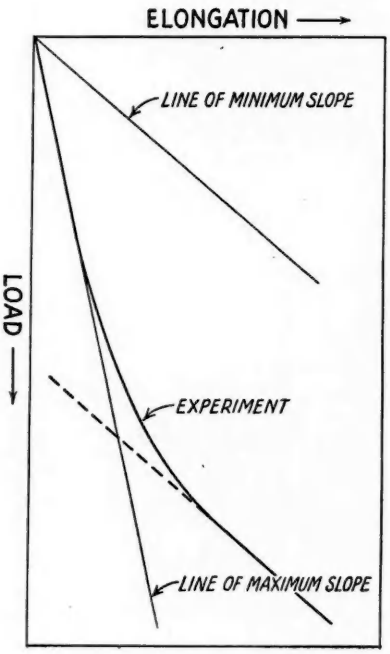

FIG. 7. *Stress-strain curve for constant rate of elongation.*

From physical considerations the strongest instantaneous Hookean constant, or, in other words, the steepest slope in the stress-strain diagram, is that of the open spring operating by itself with a stiff dashpot around the other (see Figure 7). On the other hand the smallest slope possible would occur with a free dashpot, allowing the two springs to act in series. Any actual slope will lie in between.

B. Stress as a Function of Time at a Constant Rate of Elongation

*1. Properties of the Stress-Strain Diagram.** When the fiber is elongated at a constant rate, the stress-strain curve produced will be confined by two lines from the origin with the slopes discussed (see Figure 7). It will begin at the first or steep slope, and then bend over to the second as the force gets quite large. In the end, the path of the stress-curve parallels the line of minimum slope, at a distance representing the constant force necessary to move the dashpot at a constant rate. Thus the relationship is two straight lines connected by a transition region.

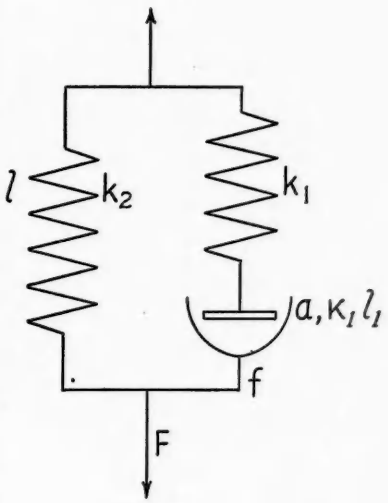

FIG. 8. *Notation for a three-element system: l is here the elongation per unit length and k is the corresponding force constant; κ has the dimensions of a frequency. It represents the frequency with which an unstrained segment jumps forward multiplied by the ratio of two distances, the distance jumped to the distance between successive jumping segments in the direction of flow; α is the volume of the flow unit divided by $2kT$.*

*In Figure 7 and in subsequent stress-strain curves the stress is plotted down instead of up as is usual. The graphs were obtained on the machines in this form.

The maximum slope is difficult to determine exactly, but it is the initial slope of the curve. The minimum slope can be determined by elongation at a very slow rate at which the dashpot offers no resistance to flow. The simple way of finding this slope, however, is to allow the fiber to relax at constant length until a constant load is achieved. This is the load that would have resulted from a slow pulling, and with this value the line may be accurately constructed.

2. Derivation of the Stress-Strain Relationship. For convenience the arrangement of the elements will be altered to one which is entirely equivalent (that is, leads to the same solution). In Figure 8 symbols are written opposite the elements to which they apply.

Now the force $F - f = k_2 l$ (by Hooke's law), where l is the total elongation per unit length of fiber. Furthermore, $f = k_1 l'_1$. By the hyperbolic sine law:

$$\frac{dl_1}{dt} = \mathrm{K} \sinh \alpha f$$

from the above

$$\frac{dl_1}{dt} = \rho - \frac{1}{k_1}\frac{df}{dt}$$

where the rate of elongation $\rho = dl/dt$, a constant.

$$\frac{1}{k_1}\frac{df}{dt} = \rho - \mathrm{K} \sinh \alpha f.$$

Absorbing scale factors by the substitutions

$$\tau = K\alpha k_1 t,$$

$$\varphi = \alpha f,$$

$$\frac{d\varphi}{d\tau} = \beta - \sinh \varphi$$

where $\beta = \rho/\mathrm{K}$ and, integrating, one obtains:

$$\frac{2}{\sqrt{1+\beta^2}} \tanh^{-1} \frac{e^{+\varphi} - \beta}{\sqrt{1+\beta^2}} = \tau - c.$$

Solving this equation for φ and remembering $\varphi = \alpha f$, one obtains:

$$f = \frac{1}{\alpha} \log \left\{ \beta + \sqrt{1+\beta^2} \times \tanh \left[\frac{\sqrt{1+\beta^2}}{2} (K\alpha k_1 (t - c)) \right] \right\}.$$

Applying the following conditions to achieve a

reduced equation: when

$$t = 0, \quad f = 0,$$
$$t = \infty, \quad f = 1,$$
$$t = 1, \quad f = \tfrac{1}{2},$$

and solving for f, one obtains:

$$f = \frac{\log \left\{ \dfrac{1 + \dfrac{1+\beta}{\sqrt{\beta^2+1}} \tanh (A)t}{1 + \dfrac{1-\beta}{\sqrt{\beta^2+1}} \tanh (A)t} \right\}}{\log \left\{ \dfrac{1 + \dfrac{1+\beta}{\sqrt{1+\beta^2}}}{1 + \dfrac{1-\beta}{\sqrt{1+\beta^2}}} \right\}}$$

where

$$\tanh (A) = \left\{ \frac{\sqrt{\left(\frac{\beta+1}{\sqrt{\beta^2+1}}\right)\left(\frac{1-\beta}{\sqrt{\beta^2+1}}+1\right)} - 1}{\left(\frac{\beta+1}{\sqrt{\beta^2+1}}+1\right)\left(\frac{1-\beta}{\sqrt{\beta^2+1}}+1\right) - 1} \right\}.$$

3. Discussion of the Function: f. The purpose of the conditions imposed on f was to obtain a reduced equation; that, is to make the solutions coincide at $t=0$, 1, and ∞ by adjustment of the two scale factors $K\alpha k_1$ and α and the constant of integration c. The curves will diverge at all other points as a function of β. Now f_2, the value of f at the point $t = 2$, is investigated for the purpose of determining β.

In the case of Newton's viscous flow, $f_2 = 0.75$. This is most readily shown by solving the Newtonian case of this same problem. This is, of course, the limiting case for β small. For β large, f_2 approaches unity. Thus, with the value of f_2, β may be determined. (The curve of β vs. f_2 is given in Figure 9.)

4. Evaluation of the Constants. Comparing the two equations for f one finds

$$K = \frac{\rho}{\beta}, \quad \alpha = \log \left\{ \frac{1 + \dfrac{\beta+1}{\sqrt{\beta^2+1}}}{1 + \dfrac{1-\beta}{\sqrt{\beta^2+1}}} \right\} \approx \log 2\beta,$$

if β is large, and

$$k_1 = \frac{2(A)}{K\alpha\sqrt{1+\beta^2}}.$$

By inspection of Figure 8 and remembering that for the small initial loading the dashpot does not move, one sees that initially $F = (k_1 + k_2)l$, that is,

$$\left(\frac{dF}{dl}\right)_{\text{initial}} = k_1 + k_2, \quad \text{and} \quad \left(\frac{df}{dt}\right)_{\text{final}} = k_2$$

for the final slope. Thus one has also

$$k_1 = \left(\frac{dF}{dl}\right)_{\text{initial}} - \left(\frac{dF}{dl}\right)_{\text{final}}.$$

From the above explicit expressions for f and $(F - f)$ the total force can be written as a function of t, as follows:

$$F = f + (F - f)$$
$$= f + k_2\rho t.$$

5. Deviations from the Predicted Behavior. The most important deviation is an apparent weakening of the springs at some time or other. Actually an apparent weakening of the springs can arise from the removal of elements by breaking, thus decreasing the total number in a cross section, but probably leaving individual elements unchanged. The fiber must necessarily break and thus finally deviate from the predicted line of minimum slope. Now, at times, this deviation is apparent only at the moment the filament breaks; in cases exhibiting discontinuous breakage such as this, the conclusion must be that the break is due to a flaw of very short length, not long enough to contribute to the general strain. On the other hand, the fiber often continuously loads at a decreasing rate (in the case

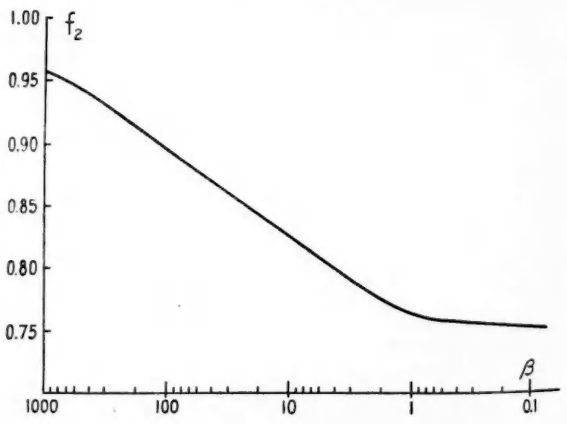

FIG. 9. *Diagram for evaluating β from the reduced force, f_2, acting on the dashpot at a time which is twice the time elapsed from the application of load until it reaches one-half its final value.*

of a rutile-loaded viscose apparently reaching zero) in a reversible or at least partially reversible manner. This shows that at times peculiarly non-Hookean springs may have to be incorporated into the model. However, the analytical difficulties are quite great and, except for special models of little interest, no progress has been made.

Another deviation concerns the hyperbolic viscous element. In determining the line of minimum slope by relaxation it sometimes is noted that the last few percents of the load to be relaxed relax at a very slow rate, superficially predicting the presence of a very stiff dashpot. However, using this value for the final slope, it is seen that the fiber already gives this slope over an extended range even in the beginning portion after the knee; that is, the relaxation curve appears to be in two segments with two dashpots, while the elongation curve does not show the presence of the two elements at all. The explanation apparently lies in a sort of thixotropy, and thus involves elements which are changed by the flow itself.

6. A Sample Calculation. As an example of the convenient method of evaluating the constants, a sample calculation is shown: The stress-strain curve in Figure 10 has been observed. A line is constructed from the origin parallel to the final slope (Figure 11), and intersecting the line of ultimate relaxation at the end of the elongation (Figure 10).

The time, t_1, where $b=1/2a$ in Figure 11, is found (conveniently by means of proportional dividers). In this case $t_1=6$ seconds. Then the length of the line c, at $t_2 = 2t_1$, or 12 seconds, is measured, and the ratio of c to a calculated. In this case 0.85 is the value obtained.

Then β is determined from Figure 9 to be $\beta = 22$. Now the rate of elongation is 0.0036 second^{-1} and thus

$$K = \frac{\rho}{\beta} = \frac{0.0036}{2} = 1.6 \times 10^{-4} \text{ sec}^{-1}$$

and

$$\alpha = \log \left\{ \frac{1 + \dfrac{1+\beta}{\sqrt{\beta^2+1}}}{1 + \dfrac{1-\beta}{\sqrt{\beta^2+1}}} \right\}$$
$$= 3.8 \text{ reduced units.}$$

The value in c.g.s. units is $3.8/a$.

As the area of the fiber was 1.75×10^{-5} cm^2 and each division on the scale is 1.98 grams,

$$a = 1.0 \times 10^9 \text{ dynes per cm}^2$$

and

$$\alpha = 3.8 \times 10^{-9}.$$

Now

$$\alpha = \frac{V_f}{2kT},$$

whence $V_f = 3.2 \times 10^{-22}$ or 7Å cubed. Now

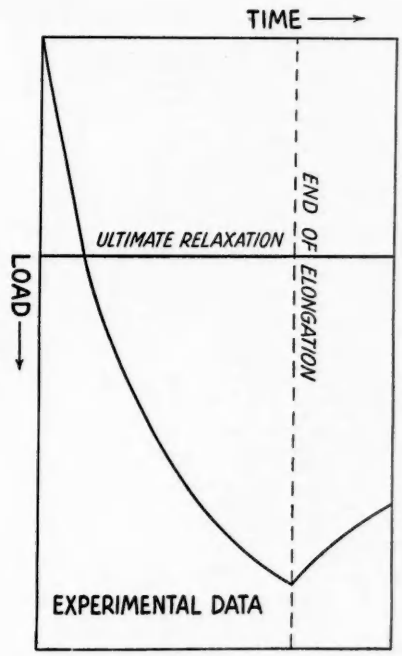

FIG. 10. *Stress-strain curve for a constant rate of elongation for a viscose rayon fiber.*

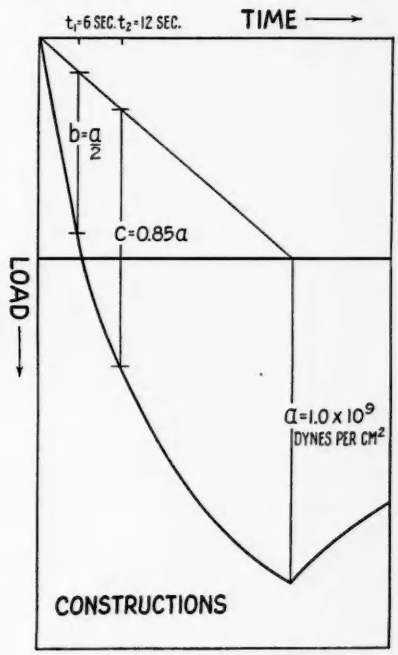

FIG. 11. *Construction used in fitting theoretical equations to experimental data.*

$$K = 2\frac{V_f}{V_m}\frac{kT}{h}e^{-\Delta F^{\ddagger}/RT},$$

and taking V_m as the dimensions of the cellulose residue, $10.3 \times 8.35 \times 7.9$ Å^3,

$$\frac{V_f}{V_m} = 0.47$$

and

$$\Delta F^{\ddagger} = 23{,}450 \text{ cals.}$$

(The energy is not especially sensitive to V_f/V_m.) Interpreting the results in terms of Figure 6, the elastic constants are determined from the slopes to be: outside spring $k = 2.0 \times 10^{11}$ dynes/cm^2, the spring on the dashpot $k = 6.0 \times 10^{11}$ dynes cm^{-2}.

C. The Relaxation of Stress at a Constant Elongation

1. Derivation. It is of interest to consider the special case of the preceding argument when $\rho = 0$. The general expression becomes undefined, as β is always zero, and thus it is most readily solved as a special case. The single, isolated spring (Figure 8) contributes a constant force and leaves the transient force on the Maxwell element to be considered. In the same notation as above

$$\frac{-1}{k_1}\frac{df}{dt} = K \sinh \alpha f$$

as $\rho = 0$. Making the substitutions

$$\tau = -K\alpha k_1 t, \quad \varphi = \alpha f$$

one has

$$\frac{d\varphi}{d\tau} = \sinh \varphi.$$

Integrating,

$$\log \tanh \frac{\varphi}{2} = \tau + c$$

or

$$\log \tanh \frac{af}{2} = bt + c.$$

Now, choosing dimensions so that when

$$f = 1, \quad t = 0, \quad \text{and} \quad t = 1, \quad f = \tfrac{1}{2},$$

one finds

$$c = \log \tanh \frac{a}{2}$$

and

$$b = \log \frac{\tanh \frac{a}{4}}{\tanh \frac{a}{2}},$$

whence

$$\log \left\{ \frac{\tanh \frac{af}{2}}{\tanh \frac{a}{2}} \right\} = t \log \left\{ \frac{\tanh \frac{a}{4}}{\tanh \frac{a}{2}} \right\}.$$

Now, if at $t = 2$, f is investigated, it will be a function of a and thus from a value of f_2, a is evaluated.

The computed curve is given in Figure 12.

2. Relaxation of Rayon. Illustrated in Figure 13 is an experimental curve showing the stress relaxation of a rayon. A was evaluated in the manner described, and

$$\text{since} \quad a = \alpha \quad \text{and} \quad b = K\alpha k_1$$

the value of α and of the product of K and k_1 could be calculated. α was found to be 4.2, and, as this experiment formed the latter half of a constant-rate-of-elongation experiment, this could be compared with a value of 3.8 for α in the first part (reduced units). The agreement for the value of k_1K was within 10 percent, which reflects even less change in the activation energy. (Ca. 100 calories.)

3. Creep. Since the case of creep is governed by the same differential equation, an entirely analogous argument allows the fitting of creep curves. The same functional diagram is used (Figure 12), except that the reduced elongation is subtracted from unity, as creep is increasing as relaxation decreases.

As one of the examples in his valuable book, Leaderman [8] gave the illustrated example (Figure 14) of the creep in a twisted iron wire. It was fitted as closely as possible with a single Maxwell

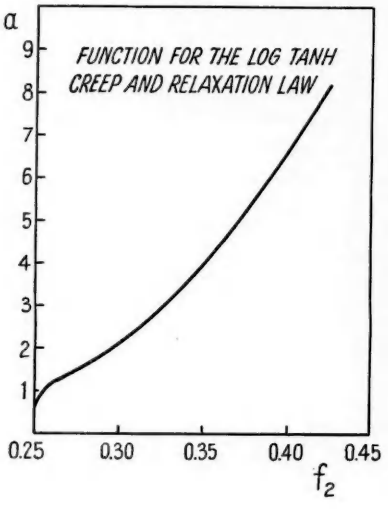

FIG. 12. *Diagram for evaluating a from the observed reduced force, f_2, acting on the dashpot at a time which is twice the time from the beginning of the relaxation to the time when the force reaches one-half of its initial value.*

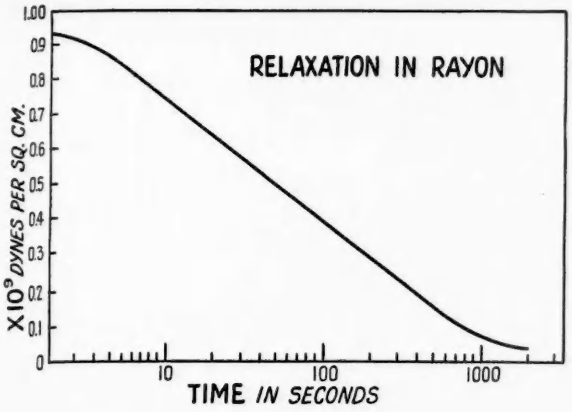

FIG. 13. *The relaxation of stress in rayon. A continuation of the experiment illustrated in Figure 10.*

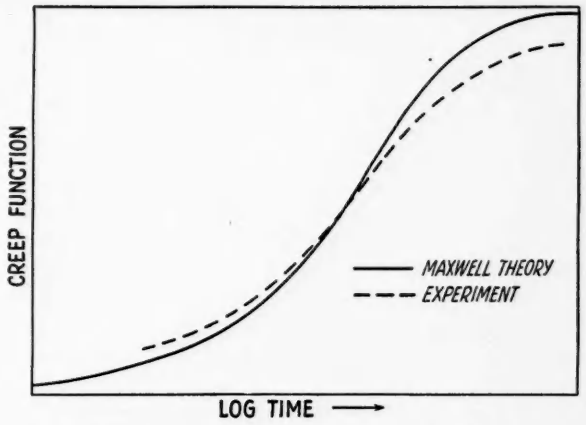

FIG. 14. *A curve taken from Leaderman's book [8] illustrating the inadequacy of a single Newtonian relaxation time.*

element but the inadequacy of this as well as the unsymmetricalness of the fit can be seen from the figure. Because of this lack of symmetry, even the Wiechert modification would be only partially successful. However, the use of the preceding argument fits the experimental data, reproducing the asymmetry within the limits of experimental error.

It should be noted that the total length of the ordinate in Figure 14 which represents Leaderman's creep function, is, in this case, equivalent to an angular displacement of 4.2°.

V. A Study of Moisture in Rayon

The following is an application of the preceding theory to the effect of moisture on a rayon* whose humidity moisture curve is given in Figure 15.

To determine the exact nature of the effect of water on the mechanical properties of a rayon fiber, a particular fiber was elongated at various humidities. In liquid water the fiber absorbs enough water so that in terms of the three-element model the dashpot becomes very loose and quite Newtonian. In the absence of moisture, as with a vacuum-dried fiber, the dashpot stiffens so much that over moderate ranges of elongation the fiber is like a simple spring. Thus, at either extreme, it is impossible to determine the structural constants discussed above.

To determine the effect on the viscous-element constants considered separately, the intermediate range of humidity was investigated.

A. Experimental Results

The size of the flow unit remains substantially constant at 7–7.5Å except below a relative humidity of about 0.005, when the flow units begin to amalgamate as the dashpot ceases to function. α, from a humidity of 1.00 to 0.85, is less than one, because the force on the dashpot is small; and, since below about one the behavior is essentially Newtonian, there is no way to determine β. At a relative humidity of 0.57, β becomes 10–12, corresponding to an activation free energy of 20,700 calories, if $V_f/V_m = 0.47$. At 0.04 relative humidity β is ca. 165, corresponding to 23,300 calories. Throughout the middle range of humidities where the water content is not changing rapidly (Figure 15) the activation energy changes very little with

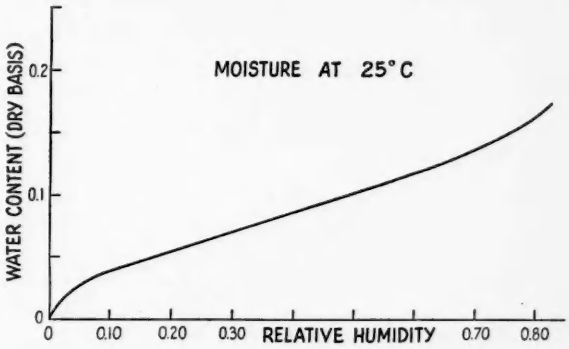

FIG. 15. *Water content versus relative humidity for the rayon fiber which is used in all of the experiments in this paper. (This curve was made available to us through the courtesy of E. I. du Pont de Nemours & Co.)*

* The rayon and the moisture curve, as well as much other valuable information and material, were furnished us by Mr. C. R. Humphries of the Rayon Department of E. I. du Pont de Nemours & Co., to whom we are greatly indebted.

moisture content. The experimental error due to various irregularities in the fibers is often greater than the variation caused by moisture in this range. Below a humidity of 0.005, β becomes very large, so that the activation energy exceeds 24,500 calories. For activation energies greater than this, flow becomes too slow to be measured.

The open spring (the initial slope—see Figure 9) remains substantially constant at $2 \pm 0.1 \times 10^{11}$ dynes per cm^2 over the whole range of humidities. Under intensive drying it strengthens to 3×10^{11} dynes/cm^2. The corresponding humidity is beyond the range of these experiments, however, and is being investigated more fully.

The spring in parallel with the dashpot has a constant of $0.80–0.85 \times 10^{11}$ throughout the range of the experiment except for extreme dryness, when the units of flow begin to amalgamate. This reinforces the spring until it becomes completely stiff. During this process, the drying dashpot apparently gains a certain elasticity.

B. Conclusion

The conclusion one reaches, then, is that the water changes only the activation energy and thereby serves as a sort of lubricant, not changing the flow process at all and altering the structure none except as complete drying is approached.

C. Description of Apparatus and Technique

The apparatus was that of Sookne and Rutherford, National Bureau of Standards, RP1546 (1943), an autographic constant-rate-of-elongation balance controlled by a photoelectric circuit. A single fiber was mounted in a test tube, and conditioned for a week over sulfuric acid of the proper concentration. The fiber was submerged in conditioned mercury (Figure 16), and the stress-strain curve prepared on the Sookne-Rutherford balance. The purpose of the mercury was to provide a seal to maintain the proper moisture content in the fiber.

VI. A Discussion of the Validity of the Hyperbolic Sine Law

In the light of the preceding experiments one may now consider the question of using the hyperbolic sine law for any viscous element. The most important advantage of the change, as was discussed above, is the ability to interpret the results in terms of a chemical model. Aside from this, the agreement with experiment may be considered. With a Newtonian viscous element, as was stated, the shape factor, β, of a stress-strain curve is fixed outside the scale. The variations from this factor, which have been discussed above, usually have been as high as 10 percent.

An important conclusion concerning distributions may be made in light of the experiments above. As the reader will notice, the effect of increasing deviation from Newtonian behavior under the conditions of constant rate of elongation is to make the transition between the initial and final slopes sharper and sharper. In the limit the dashpot yields suddenly at $t = 2$ (reduced) and the transition region is eliminated. A distribution of relaxation times will have the opposite effect of rounding off the transition. Thus for a Newtonian distribution f_2 will always be *less* than 0.75. The need for a more adequate viscosity law than the Newtonian one is, therefore, unequivocally demonstrated. The reality of the improvement made is shown by the manner in which the same function with constants unchanged predicts the contiguous relaxation.

Finally, it may be stated that, in the light of the present reaction rate theory, with forces as large as 10^9 dynes per cm,^{2} Newtonian viscosity would occur only with a flow unit of very small size, in some cases of the order of an atom. It should not be concluded that, because the authors believe a distribution of Newtonian relaxation times is inadequate as an explanation of viscous behavior, they also believe that a distribution of elements is now an established fact. The presence of this distribution is apparent in a long creep curve, but

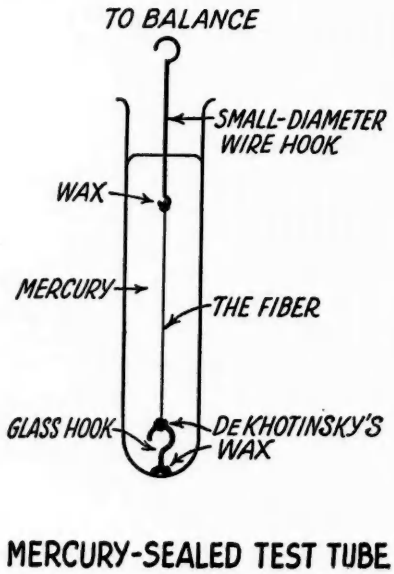

FIG. 16. *Schematic diagram of the apparatus used in conjunction with the Sookne-Rutherford apparatus to conduct experiments at various humidities without a conditioned room.*

absolute evidence for the presence of a number of different relaxation times is the reversal of motion as found by Kohlrausch. One of his results for a twisted rubber thread shows at least three relaxations. This observation, however, puts only a lower limit on the number of elements. Also, Newtonian behavior could very well be found under the proper conditions, but, inasmuch as it is a special case, it is contained in our considerations.

VII. Types of Experiments

Several types of experiments have been used from time to time. Although they all have the same theoretical basis, some tend to emphasize one type of behavior over another.

A. Longitudinal Experiments

1. Creep with Constant Load. For a given elongation, a creep experiment tends to be most destructive of the fiber, accentuating the faults, as it must, since it eventually leads to breakage. One discovers the various relaxations one after another, and since these units are independent of one another, and often widely spaced, the attempt to "fit" them all with one function is likely to be pointless, if not fruitless. They are ideal experiments for qualitative pathfinding purposes, since they are easily run, and are drastic enough to bring out all the yielding mechanisms.

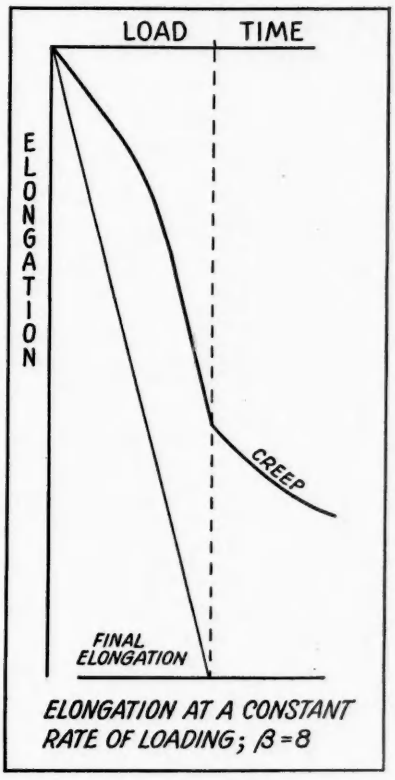

FIG. 17. *Experimental stress-strain curve at constant rate of loading, showing the analogy between this type of experiment and the constant rate-of-elongation experiment, as in Figure 10.*

Due to the bonds that are broken irreversibly, the hysteresis of recovery may show solid friction; that is, friction that does not disappear with velocities that can be measured.

2. Stress Relaxation at Constant Length. Stress-relaxation-at-constant-length experiments are similar to creep experiments, but are much less drastic, since the fiber is never broken. However, as discussed above, when the stress is almost completely decayed there is opportunity for thixotropy because of the slow rate of relaxation.

3. Constant Rate of Loading. This is the form of experiment in commercial machines which operate on the inclined-plane principle. The distinctive feature of experiments of this kind and the one that follows is the fact that the particular rate selected emphasizes one relaxation time, and thus makes interpretation much easier. Owing to the fact that the rate of loading is constant, the rate of elongation constantly *increases*, so that this is a drastic method compared to case 4 (below).

4. Elongation at a Constant Rate. This case has been discussed above. The theory of the three-element model developed for case 4 applies directly to case 3, as the differential equations governing both are identical in form, except that the rate of elongation is replaced by the rate of loading divided by the spring constant, etc.

The curve shown in Figure 17 is a constant-rate-of-loading experiment on the same rayon with which the moisture experiments were conducted. The humidity was that of the room, about 65 percent. The apparatus was an original one, to be discussed in a later paper.

5 and 6. Experiments with a Sinusoidal Rate of Loading or Extension. Experiments of this type are of great interest but, unfortunately, when a hyperbolic sine relationship is used for the viscosity, integration of the equation is impossible except in series. They are discussed by Tobolsky and Eyring [10].

B. Torsional Experiments

Torsional experiments may be divided into two groups. When the fiber is twisted, weighted, etc., in a manner similar to that used in the longitudinal experiments, the theory remains similar, and the results, while for a different direction in the fiber, are similar. Because angular displacement is easy

to control, much of the early data were for this type of experiment.

The second type of torsional experiment involves the moment of inertia of the weight attached, and thus adds a new complication to the experiments. Experiments of this sort are being performed on a few fibers. They are convenient for short natural fibers, when creep experiments are difficult.

The questions raised in the classical paper on the subject [11] have yet to be answered. Kelvin's work concerned metal wires, however, which seem more difficult to interpret than textile fibers.

VIII. An Analysis of Some Creep and Creep Recovery Curves of Leaderman

The data in Leaderman's [8] book on creep have been examined in terms of the three-element system, and the hyperbolic sine law viscosity. His curves for creep and creep recovery for viscose rayon, acetate rayon, silk, and nylon were fitted. Good fits were obtained in all cases with the exceptions of nylon under large loads and one curve for rayon under a very light load. Nylon curves under smaller loads can be fitted, but the curves under large loads show a definite inflection in the middle of the creep curves, indicating the presence of at least a second closed dashpot and hence making the three-element system inapplicable. The creep curve for rayon under a small load, likewise, indicates a distribution of relaxation times. However, other curves for rayon under greater loads can be fitted for both creep and creep recovery (see Figures 18 and 19). The reason for this exception is not clear. As before, all lengths will be the reduced values—that is, length divided by the original unstretched length.

The differential equations for the three-element system have already been derived.

$$\frac{dl}{dt} = \frac{1}{k_1}\frac{df}{dt} + \mathrm{K}\sinh \alpha f$$

$$\frac{dl}{dt} = \frac{1}{k_2}\frac{d(F-f)}{dt}$$

where

$$\alpha = \frac{\lambda_2\lambda_3\lambda}{2kT} \quad \text{and} \quad \mathrm{K} = 2\frac{\lambda}{\lambda_1}\frac{kT}{h}e^{-\Delta F^{\ddagger}/kT}.$$

For reversible creep under constant load the assumption may be made that the cross-sectional area of the fiber remains effectively unchanged. The condition of restraint for creep is then

$$\frac{dF}{dt} = 0 \quad \text{or} \quad \frac{dl}{dt} = -\frac{1}{k_2}\frac{df}{dt}.$$

When the dashpot has relaxed completely, $F = k_2 L_\infty$, where L_∞ is the elongation of the spring in parallel with the dashpot, which is also the maximum elongation of the three-element system under a given load, and $l_\infty = L_\infty - L_0$. Equating expressions for dl/dt

$$\left(\frac{k_1 + k_2}{k_1 k_2}\right)\left(\frac{df}{dt}\right) + \mathrm{K}\sinh \alpha f = 0.$$

Substituting

$$\frac{dl}{dt} = -\frac{1}{k_2}\frac{df}{ft} \quad \text{and} \quad f = k_2(l_\infty - l)$$

$$-\frac{d(l_\infty - l)}{dt} = \left(\frac{k_1}{k_1 + k_2}\right)\mathrm{K}\sinh \alpha k_2(l_\infty - l).$$

Integrating,

$$\frac{1}{\alpha k_2}\log\tanh\{\tfrac{1}{2}\alpha k_2(l_\infty - l)\} = -\left(\frac{k_1}{k_1 + k_2}\right)\mathrm{K}t + \frac{1}{\alpha k_2}\log\tanh \tfrac{1}{2}\alpha k_2 l_\infty.$$

Using the identity

$$\sinh 2x = \operatorname{csch}\log\tanh x,$$

$$\sinh \alpha k_2(l_\infty - l) = \operatorname{csch}\left\{-\left(\frac{k_1 k_2}{k_1 + k_2}\right)\alpha\mathrm{K}t + \beta\right\},$$

where

$$\beta = \log\tanh \tfrac{1}{2}\alpha k_2 l_\infty.$$

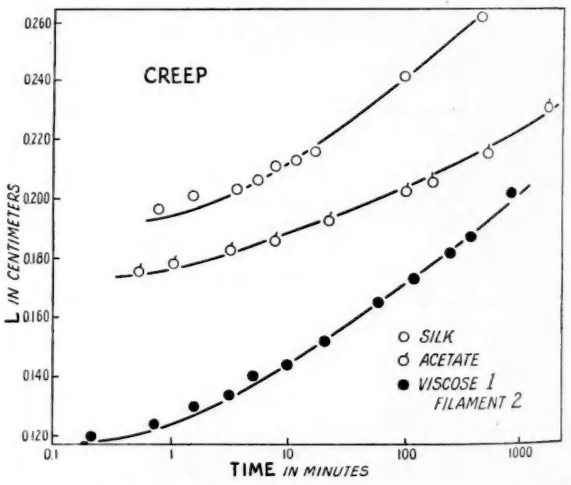

FIG. 18. *Experimental and theoretical creep curves. The experimental points are taken from Leaderman [8]. The solid curve was obtained from theory, using Hooke's law, and a hyperbolic sine law for viscous flow. If a single linear viscous element were used the curves could at best be fitted over one-third the time range above.*

Inverting,

$$\operatorname{csch} \alpha k_2(l_\infty - l) = \sinh\left\{ -\left(\frac{k_1k_2}{k_1+k_2}\right)\alpha \mathrm{K}t + \beta \right\}$$

$$= \operatorname{csch} \log \tanh\left\{ -\frac{1}{2}\left(\frac{k_1k_2}{k_1+k_2}\right)\alpha \mathrm{K}t + \tfrac{1}{2}\beta \right\},$$

whence

$$l_\infty - l = \frac{1}{\alpha k_2} \log \operatorname{ctnh}\left\{ \frac{1}{2}\gamma + \frac{1}{2}\left(\frac{k_1}{k_1+k_2}\right)\mathrm{K}\alpha k_2 t \right\},$$

where

$$\gamma = -\beta = \log \operatorname{ctnh} \tfrac{1}{2}\alpha k_2 l_\infty.$$

For the case of creep recovery the same procedure is used except that $F = 0$ and, at $t = 0$, $L = l_0$, the value of the elongation at the moment the weight is removed. The resulting equation is

$$L = \frac{1}{\alpha k_2} \log \operatorname{ctnh}\left\{ \frac{1}{2}\gamma' + \frac{1}{2}\left(\frac{k_1}{k_1+k_2}\right)\mathrm{K}\alpha k_2 t \right\},$$

where $\gamma' = \ln \operatorname{ctnh} \tfrac{1}{2}\alpha k_2 l_0$.

If the force used is small and t is of the order of 1,000 minutes or less the hyperbolic cotangent can be expanded and the first term only used for textile fibers ($\operatorname{ctnh} x = 1/x$). The resulting equations are, for creep recovery,

$$L = -\frac{1}{\alpha k_2} \log\left\{ \frac{1}{2}\gamma' + \frac{1}{2}\left(\frac{k_1}{k_1+k_2}\right)\mathrm{K}\alpha k_2 t \right\}$$

and for creep

$$l_\infty - l = -\frac{1}{\alpha k_2} \log\left\{ \frac{1}{2}\gamma + \frac{1}{2}\left(\frac{k_1}{k_1+k_2}\right)\mathrm{K}\alpha k_2 t \right\}.$$

This may be put in a form easier to handle in the following way. Changing from delayed elongations

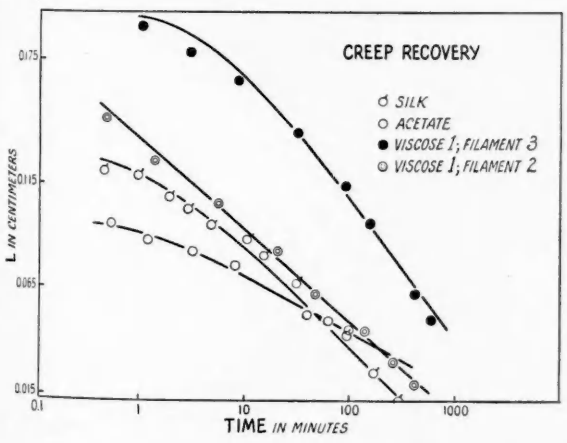

FIG. 19. *Experimental and theoretical creep recovery curves, as in Figure 18. The points are from Leaderman [8] and the solid curves are theoretical.*

to total elongations

$$(L_\infty - L_0) - (L - L_0)$$

$$= -\frac{1}{\alpha k_2} \log\left\{ \frac{1}{2}\gamma + \frac{1}{2}\left(\frac{k_1}{k_1+k_2}\right)\mathrm{K}\alpha k_2 t \right\}$$

$$= -\frac{1}{\alpha k_2} \log\left\{ \frac{1}{2}\gamma\left(1 + \left(\frac{k_1}{k_1+k_2}\right)\frac{\mathrm{K}\alpha k_2 t}{\gamma}\right)\right\}$$

$$\gamma = \log \operatorname{ctnh} \tfrac{1}{2}\alpha k_2 l_\infty$$

and since

$$\operatorname{ctnh} x = \frac{e^x + e^{-x}}{e^x - e^{-x}} = 1 + 2e^{-2x},$$

$$\log \operatorname{ctnh} x \approx 2e^{-2x} \text{ for large } x;$$

hence

$$\tfrac{1}{2}\gamma = e^{-\alpha k_2 l_\infty}$$

and

$$\log \tfrac{1}{2}\gamma = -\alpha k_2 l_\infty = -\alpha k_2(L_\infty - L_0),$$

whence

$$(L_\infty - L_0) - (L - L_0) = L_\infty - L_0 - \frac{1}{\alpha k_2} \log\left(1 + \frac{k_1}{k_1+k_2}\frac{\mathrm{K}\alpha k_2}{\gamma} t\right)$$

or

$$L - L_0 = \frac{1}{\alpha k_2} \log\left\{1 + \left(\frac{k_1}{k_1+k_2}\right)\frac{\mathrm{K}\alpha k_2}{\gamma} t\right\}$$

where L_0 is the instantaneous elongation.

The values of the constants used to fit the figures given are shown in Tables I and II. The experimental and theoretical curves are given in Figures 18 and 19. The points represent Leaderman's data; the smooth curves have been calculated.

For longer times, $\frac{1}{2}\gamma'$ becomes unimportant and $L - L_0$ is a linear function of $\log t$. The slope of the straight line and evaluation of a point on the line give αk_2 and $\frac{1}{2}(k_1/k_1 + k_2)\mathrm{K}\alpha k_2$, respectively. γ' is evaluated from the known value of L_0 and the derived value of αk_2.

The equation for creep under a small force was fitted to three points in the following way:

$$L_1 - L_0 = A \log(1 + Bt_1),$$

$$L_2 - L_0 = A \log(1 + Bt_2),$$

$$L_3 - L_0 = A \log(1 + Bt_3),$$

$$L_1 - L_2 = A \log\left\{\frac{1 + Bt_1}{1 + Bt_2}\right\},$$

$$L_1 - L_3 = A \log\left\{\frac{1 + Bt_1}{1 + Bt_3}\right\},$$

$$\frac{L_1 - L_2}{L_1 - L_3} = \frac{\log\left\{\frac{1 + Bt_1}{1 + Bt_2}\right\}}{\log\left\{\frac{1 + Bt_1}{1 + Bt_3}\right\}} = \Phi(B).$$

TABLE I. CREEP RECOVERY

Substance	αk_2	$\frac{1}{2}\frac{k_1 K}{k_1 + k_2}$ sec^{-1}	$\frac{1}{2}\gamma'$
Silk—load 1.053 g.	1,330	2×10^{-8}	0.0015
Viscose 1. Filament 3—load 1.053	902	5.5×10^{-9}	0.00131
Viscose 1. Filament 2—load 0.856 g.	2,300	2×10^{-9}	0.00023
Acetate—load 1.480 g.	1,490	7.5×10^{-9}	——

A plot of $\Phi(B)$ against (B) was constructed for fixed values of t_1, t_2, t_3, and B was determined from this (plot not shown). A was determined from $L_1 - L_2$ and L_0 from $L_3 - L_0 = A \log (1 + Bt_3)$.

$$A = \frac{2.3026}{\alpha k_2}, \quad B = \left\{\frac{k_1}{k_1 + k_2}\right\}\frac{K\alpha k_2}{\gamma}.$$

It should be noted that the term γ in each case makes the equation different from the corresponding equation using Newtonian flow. This is an important term inasmuch as these equations reproduced Leaderman's curves over four cycles of logarithmic time. A Newtonian curve will fit for only about a cycle and a half.

The volume of the flow unit and the flow activation energies were determined using Leaderman's values of the cross-sectional area of the fibers and instantaneous moduli (which are given here for reference) and the assumption that the two spring constants are the same and that V_h/V_m equals one-half. The values obtained both from creep and creep recovery are given in Tables III and IV.

TABLE III. LENGTH OF FLOW UNIT $\sqrt[3]{\lambda_2\lambda_3\lambda}$ IN ÅNGSTROMS

Substance	Fiber cross-sectional area $cm^2 \times 10^8$ (from Leaderman)	Instantaneous modulus kg/mm^2 (from Leaderman)	Length of flow unit from creep recovery (Å)
Silk	102	1,312	11
Viscose rayon	178*	1,094	11
Viscose rayon (pre-stretched)	356	1,420	16
Acetate	267	576	16

* Derived from denier and the value for the pre-stretched viscose.

TABLE II. CREEP

Substance	$B_{sec^{-1}}$	A	L_0
Acetate load 0.856 g.	0.0065	2.79×10^{-4}	0.00625
Silk load 0.856 g.	0.0043	5.55×10^{-4}	0.00684
Viscose I load 0.856 g.	0.011	4.47×10^{-4}	0.00423

The close proximity of all of the flow activation free energies to the value 25 kg. cal. is a definite indication that the mechanism of the flow process is similar in the various fibers despite the differences in chemical properties. It is difficult to say whether the difference in size of the flow units for creep recovery has a physical significance or will disappear with improved theoretical and experimental techniques. Further work on this point will be done in the future. Leaderman's creep curves do not give values for L_∞. We were therefore obliged to use γ in determining our activation energies, volumes, and elastic constants. The elastic constants thus obtained are about an order of magnitude too large. Creep data extending over longer intervals will be required to resolve this difficulty.

The activation energy for the flow in acetate has also been considered by Leaderman. At temperatures of about 90°C the calculated activation energy, 51 kg. cal., is nearly double that found at 50°C, 29 kg. cal. from one set of measurements, although a value of 49 kg. cal. is found at 50°C from a different set of measurements. This indicates that the mechanism of flow has changed. Such a change in mechanism invalidates the simple calculation of an activation energy from the equation of Arrhenius. From Leaderman's data it appears that the flow mechanism, and hence the activation energy, depends on the temperature and also on the physical state of the fiber. A theoretical analysis which takes account of the changing

TABLE IV. FLOW ACTIVATION FREE ENERGY (cal./mole at 20°C)

Substance	Creep	Creep recovery
Silk	25,300	24,600
Viscose	24,700	28,400
Viscose pre-stretched	25,300	——
Acetate	24,900	24,700

structure of fibers with temperature will be necessary before calculated activation energies have their usual simple significance.*

Literature Cited

1. Lamb, Horace, "Hydrodynamics," Cambridge, Eng., The University Press, 6th Ed., 1932.
   Love, A. E. H., "The Mathematical Theory of Elasticity," Cambridge, Eng., The University Press, 1892–1893 (4th Ed., 1927).
2. Hooke, Robert, "De Potentia restitutiva," London, 1678.
3. Hagen, G., *Poggendorfs Ann.* **46**, 423 (1839).
   Poiseuille, J. L. M., *Comptes Rendus* **11**, **12** (1840–1841), *Mém. des Sav. Étrangers* **9** (1846).
4. Prandtl, L., and Tietjens, O. G., "Applied Hydro and Aero Mechanics," New York, McGraw-Hill Book Co., 1934.
   Reynolds, O., *Phil. Trans.* **177**, 157 (1886).
5. Mooney, M., *Physics* **7**, 413 (1936), concerning raw milled rubber, treated by Smallwood, H. M., *J. Applied Phys.* **8**, 505 (1937).
6. Wiechert, E., *Ann. Physik.* **50**, 335, 546 (1893).
7. Wall, E. T., *J. Chem. Phys.* **10**, 485 (1942).
   Guth, E., and James, H. M., *J. Chem. Phys.* **11**, 455 (1943).
8. Leaderman, H., "Elastic and Creep Properties of Filamentous Materials and Other High Polymers," Chap. VI, Washington, D. C., The Textile Foundation, 1943.
   Meyer, Kurt H., and Lotmar, Walter, Sur l'élasticité de la cellulose, *Helvetica Chimica Acta* **19**, 68 (1935).
9. Glasstone, S., Laidler, K. J., and Eyring, H., "The Theory of Rate Processes," New York, McGraw-Hill Book Co., 1941.
10. Tobolsky, A., and Eyring, H., Mechanical Properties of Polymeric Material, *J. Chem. Phys.* **11**, 125 (1943).
11. Thomson, W. (Lord Kelvin), *Proc. Roy. Soc.* **14**, 289 (1865).

*We should like to express our appreciation to Dr. R. E. Powell for valuable discussions.

Patent Abstracts

COMMENCING with this issue TEXTILE RESEARCH JOURNAL will carry brief abstract references to current patents. These references will indicate the principal improvement in the device or the process upon which the patent is based. They follow the abstracts of the journal literature (page 332). In view of the present difficulty in obtaining copies of the original patents promptly, readers of the JOURNAL may wish to have photostat copies of those in which they are particularly interested. These will be furnished at a cost of 25 cents per page.

Fiber Society Cancels Fall Meeting

THE fall meeting of the Fiber Society scheduled for September at the Philadelphia Textile School, Philadelphia, Pa., has been canceled. The present overcrowded railroads along with the fact that many of the Society's members are out of the States on special Government and Army assignments caused the Arrangements Committee to make the recommendation that the fall meeting be canceled.

University or Industry?

Laurence A. Hawkins

Executive Engineer, General Electric Company, Schenectady, New York

INDUSTRIAL research, in its relations to the company supporting it and to the public, has been exhaustively discussed in a vast number of published articles, but what may be a more nearly fundamental aspect of the subject has been relatively neglected. The value, both to industry and to the public, of the total research activity in the country depends, first, on the number and ability of the nation's research men and women, and, second, on the placement of each researcher where his aptitudes may have fullest oportunity for development and exercise. The latter depends largely on the judgment shown by the graduate or postgraduate student in selecting the institution in which he is to work. It is hoped that this article may help in the formulation of that judgment.

The first and most important choice which must be made in planning a research career in the physical sciences is between university and industry, and fortunately it is a choice to which certain general principles are applicable. That decision having been made, the selection of a particular university or a particular industrial laboratory will be determined by a variety of special considerations, such as field of interest, personalities, opportunity, conditions of work, location, etc., which vary in weight with the individual research man and do not lend themselves readily to helpful generalizations. The following discussion will therefore be confined to the single question—university or industry?

The amount of salary should not greatly influence the decision. While to some extent colleges and industry are in competition, since both draw their research men from the same source, there should not be a bidding against each other for scientifically trained men. Industry must continue to look to the colleges for its trained scientists; so, if it were to entice all the best men away from the colleges by outbidding them with offers of high salaries, it would be committing a folly similar to that of trying to increase one's income by spending one's capital. Of course it should be borne in mind that the base rate of salaries should be higher in industry than in college, since a college instructor or professor, with vacations and probable opportunities for consulting work, is often able to augment his income very materially in a way not available to the man in industrial research.

Fortunately, there is sufficient diversity in aptitude and inclination among science graduates and postgraduates for some to be happier and more effective in university work than in industry, while others find their greatest satisfaction in an industrial research laboratory. It is to the advantage of both college and industry that each individual find the most congenial environment.

Some men have natural ability as teachers, and teaching appeals to them so strongly that research takes second place in influencing choice. Such men will turn naturally to the college or university as offering the broadest field for the exercise of their aptitude and the gratification of their ambition. Opportunity for teaching is not wholly lacking, however, from industrial laboratories. Group leaders have the duty and privilege of training their new assistants. Some of the larger industries have come to realize the value of advanced training for their technical men, and have instituted courses in advanced engineering and other subjects. In an industrial laboratory in which advanced science courses are offered, a would-be teacher may enjoy the stimulus and satisfaction provided by a student group of more than ordinary ability and keenness to learn. But even in such laboratories, research comes first, so that those for whom teaching has the greatest allure will probably be happier in college. The following discussion is therefore addressed to those whose predominant desire is for opportunities adequate for the full exercise of whatever aptitudes they may possess for the performance of research.

In seeking such opportunities, the young scientist should first try to decide whether his aptitudes point

Reprinted, with permission, from *Technology Review*, April, 1945.

toward fundamental or applied research. By fundamental research we mean the search for new knowledge, without regard to specific applications. If the results are significant, or "relevant," they justify the work, whether they prove to have practical utility or not. Thus fundamental research differs from applied research, which seeks new facts applicable to the solution of specific problems, and in which utility of the results attained is the measure of success.

Real aptitude for fundamental research is rare. It requires a characteristic which seems to be inborn rather than cultivatable, and which can be indicated by the phrase, "scientific curiosity and imagination." It needs, too, the ability to see the unknown in the familiar. Just as, to the poet, the "primrose by the river's brim" was something more, so to the successful leader in fundamental research the commonplace phenomenon must shout its question. Newton's falling apple and Watt's dancing kettle lid may be apocryphal, but they are nonetheless veridical. They typify the significance of the commonplace to the mind having natural aptitude for fundamental research.

In applied research these rare qualities are not essential, although they may be helpful. The problem itself provides the objective. Analytical ability, resourcefulness in experiment, keen observation, and perseverance are the requisites for success, and success may vary in degree with the aptitude which the researcher can bring to bear. But without scientific imagination and the ability to see things to which most men are blind, attempts at independent fundamental research are likely to be fruitless. It therefore follows that the number of men who can achieve at least moderate success in applied research is many times greater than that of those who can hope to achieve real accomplishment in independent fundamental research.

Applied research in the physical sciences is a peculiarly appropriate activity of industry. It is such research that leads to new and better materials, new and better processes, lower manufacturing costs, and better products. In modern competition, any industrial company which neglects applied research is likely to be soon outdistanced by its rivals. Applied research is seldom a suitable activity for colleges, since for best results it should be conducted in close contact with industry. Often proximity to factory process is important, and always close relations are necessary with those who will be responsible for applying the results of the research. If a college establishes such relations with one company, it automatically erects a bar to contacts with other companies in the same field, which is inimical to the relations that should exist between it and industry in general and is therefore prejudicial to its best interests.

Of course, legitimate occasion may arise in a college for applied research in connection with the development of a new instrument or process to demonstrate the utility of a conception springing from the institution's fundamental research, but such occasions are sporadic, so that a scientist intending to make his career in applied research should always turn to the industrial laboratory.

Fundamental research is an activity specially appropriate for colleges and universities. Their prime function is the promotion of knowledge, and fundamental research is a most effective means for such promotion. For many industrial laboratories, fundamental research is too much a gamble to permit extensive prosecution of it. It is pioneering. It is always doubtful whether the results will have practical utility, and still more doubtful in what field that utility, if found, will be applicable.

There are, however, a few industrial research laboratories in which the scientist with real ability in fundamental research will find as free a scope and as wide an opportunity as at any college, and frequently with more adequate facilities. Large companies with great diversity of product and of fields of interest can justify much fundamental research, since any new fact is likely to find a useful application somewhere in their diversified fields of activity. The quantity and merit of the scientific results from such laboratories, and the importance of their contributions to the advance of scientific knowledge, are evidenced by the pages of the science journals, and by the large number of awards, including two Nobel prizes, which scientists in industrial laboratories have won.

In the research laboratory of one large industrial company, for example, in a 20-year period the members of the research staff received 20 honorary doctorates, 22 medals from scientific societies, three cash prizes including one Nobel prize, and five special awards. England, France, Italy, Sweden, and Japan were represented in the awarding agencies, and in two cases the agency was the government itself.

The fundamental researches in that laboratory

were not confined to two or three men. In the five years preceding the war, from 1936 to 1940 inclusive, 144 papers reporting fundamental researches were published by 45 authors, whose average age at the time of publication was 38, with a range from 25 to 69 years. During the same period the number of papers on applied researches numbered 169. Thus, nearly half the publications of this laboratory dealt with fundamental research. The following representative titles will give an idea of the variety of the fields explored:

Transmission of an Electron Density Disturbance Along a Positive Column in a Longitudinal Field

Anomalous Dispersion and Dielectric Loss in Polar Polymers

A Kinetic Correlation of Two Reactions Involving Hydrogen Peroxide

Notes on High-Intensity Sound Waves

Two-Dimensional Gases, Liquids, and Solids

Built-Up Films of Proteins and Their Properties

Damping Capacity—Its Variation and Relation to Other Physical Properties

Remanence in Single Crystals

The Vapor Pressure of Copper and Iron

Theory and Phenomena of High Current Densities in Low-Pressure Areas

Multiple States in the High-Pressure Discharge

Some Biological Experiments with a Condenser Discharge Type of X-Ray Tube

Interpretation of the Properties of Zinc Sulfide Phosphors

The Structure of the Insulin Molecule

A New Form of the Electromagnetic Energy Equation When Free Charged Particles Are Present

Influence of Frequency on the Electro-Optical Effect in Colloids

High-Frequency Behavior of a Space Charge Rotating in a Magnetic Field

Fission of Separated Isotopes of Uranium

Theoretical Isotherms for Absorption an a Square Lattice

From the foregoing statistics and examples, it should be evident that in some industrial laboratories a man may find full opportunity for the exercise of whatever aptitude for fundamental research he may possess.

Moreover, the man who takes satisfaction in seeing the results of his researches applied in useful concrete form has much greater opportunity for such gratification in a large industrial laboratory than in a college. Some men with the right kind of imagination keenly enjoy taking a newly discovered fact and casting around for practical applications of it. One whose chief interest is in fundamental research itself may enjoy an occasional excursion into the field of applications, while, if he does not, in the large industrial laboratory he will find colleagues able and eager to make the excursion for him. In either case, the close contact with diverse industrial activities and with the live problems they involve facilitates the search for applications and increases the chances of success.

One's personality should influence the decision between college and industry. In most industrial laboratories teamwork is required, and a man unable to take interest in the other fellow's problem or unwilling to lend a hand when help is needed which is in his power to give, may be considered a liability rather than an asset, whatever his ability in research. Even in those laboratories conducting extensive fundamental research, the men engaged in it are expected to lend a sympathetic ear, wise counsel, and sometimes a helping hand, to those in difficulty. Therefore the scientist who prefers to work apart would better seek his opportunity in some college than join the staff of an industrial laboratory.

To the scholarly mind the academic atmosphere is peculiarly congenial, and the contact with other faculty members with diversified interests is pleasurable and stimulating. The freedom of action and the long vacations are enjoyable. In a large industrial laboratory employing physicists, chemists, metallurgists, and engineers, diverse and stimulating interests are to be found, but admittedly the leisurely dignity of the college and some of its freedom are lacking. The atmosphere is rather one of action and at times of urgency. Some adherence to a schedule of working hours is to be expected. To some scientists this is unattractive, but to more it is more than offset by the constant stimulus of live problems, the excellent facilities provided without the irksome and time-consuming canvass for funds sometimes necessary in university research, the helpful support of an able staff of specialists, and the satisfaction of seeing the results of research efforts translated speedily into useful applications.

The assistance a research worker may receive in

an industrial laboratory from colleagues who are specialists in other fields is well illustrated by the following quotation from an address by Dr. A. W. Hull, assistant director of the General Electric Research Laboratory, on the occasion of his retirement as president of the American Physical Society:

"In one of our war jobs we needed some means of air-conditioning a metal mercury-vapor tube. The tube operated at 200° C, and there was needed an insulated wire winding and a non-metallic housing cylinder that would stand this temperature. Glass-insulated wire was obtained from one of the factory departments, and was impregnated with a new high-temperature silicone varnish by our chemists, who also furnished us with sheet silicone for the housing. In two weeks the problem was solved. On another job some sheet invar was needed. One of our metallurgists was able to provide curves that showed the correct composition for our purpose. Another metallurgist agreed to melt a 40-pound ingot in his induction furnace the next morning, and deliver it that same day to the factory forge shop for forging. Following this, it was rolled to the desired thickness in our laboratory metalworking department, spun into form in the machine shop, and incorporated in a tube, all within two weeks. There was no haste about these jobs. They were not 'rush' projects, but just everyday problems. Two points are to be emphasized in this matter of cooperation. The first is the advantage of having grouped together in a laboratory such a wide range of specialists that expert help can be obtained on any problem which arises. The second, and more important, is the willingness of these departments and individuals to cooperate. This is a precious thing, easily lost, but slow of growth. Like Portia's quality of mercy, it 'is not strained.' It could not be obtained, for example, in a government laboratory by passing a law."

In the attainment of the greatest satisfaction a scientist can enjoy—the recognition of his achievements by his fellow-workers—there is little to choose between college and those industries which are sufficiently enlightened to permit and encourage publication of results by their laboratory men. In fact, such difference as exists seems to be in favor of such industries. The worker in an industrial laboratory often has the advantage of better facilities and help when needed from able colleagues, while commercial considerations lead an industry to publicize, as widely as professional dignity will permit, the achievements of its research men.

In opportunity for contacts with fellow scientists in other institutions, there is little difference between the college and most industrial laboratories. The same enlightened policy which leads a company to encourage publication by its research men dictates liberality in sending its men to the meetings of scientific societies, to present their papers, participate, in discussions, and extend their acquaintance with fellow scientists with similar interests. It also encourages interchange of visits with both collegiate and industrial scientists.

There is no danger of isolation in the modern industrial research laboratory.

A man will always do his best work in an environment which is most congenial. Many will continue to find their most agreeable surroundings on the college campus. Fortunately so, for it is for the best interests of college and industry alike that the colleges draw to themselves an adequate supply of the ablest science graduates. But those to whom the associations and opportunities of the world of industry appeal may be pleasurably surprised to find today in many an industrial laboratory much of the freedom of action, stimulus of intellectual contact, and freedom to publish results which formerly were to be found only in college or university.

Effects of Textile Auxiliaries on Fibers

H. C. Borghetty

General Dyestuff Corporation

ALTHOUGH the study of the effects of textile auxiliaries on fibers is my daily occupation, I have always felt a gap between the technical facts of the behavior of the various chemicals on textile fibers and the scientific explanation of these behaviors. I can present no new theories on the subject which would satisfy a group of scientific investigators, but a series of observations on the effects of textile chemicals in their relation to fibers may be of interest.

The textile industry, which provides the second most essential requirement of man, is awakening from a long slumber to find itself in the transition period between Art and Science. Unfortunately, this occurs at a time when only a small group of workers, compared to other more recent fields of industry, are engaged in fundamental research. The textile industry formerly did not want and did not attract scientific minds, nor could the scientist acquire the essential technical information without losing his detached point of view and becoming a drifter in the river of textile "notions and skills."

The lack of scientific interpretation for the phenomena which occur in the field under discussion is common knowledge. It is of interest to note, however, that as the slumbering textile giant awakens and finds the research chemists unfamiliar with market demands, looking in other directions and slow to create substitutes for the textile millennium, he blames them for the lag in progress and the fetters of decades of misuse of technical knowledge. The industry now abounds with numerous problems, some partly solved, some not, but all present a challenge to research. The following is a list of subjects on which much work is still required: (1) water repellency, (2) variations in fabric "feel," (3) wearability (abrasion resistance), (4) non-shrink—stabilized fabrics, (5) non-slip fabrics, (6) acid fading control, (7) flame resistance, (8) mildew repellency, (9) antisepsis, (10) synthetic detergents, (11) wetting agents, (12) rewetting agents, (13) delustering agents, (14) dyeing assistants to help leveling, (15) dyeing assistants to improve fastness properties, (16) crush resistance, (17) moth resistance, (18) glazing agents.

This paper was read before the American Association for the Advancement of Science, Gibson Island (Baltimore), July 10, 1945.

Wetting Agents

Wetting agents play one of the dominant roles in the textile industry. A few of their functions are the following: wetting of raw stock, penetrant for size mixtures, desizing assistant, kier boiling, wetting of skeins and packages, dyeing with all types of dyes and fibers, conditioning and wet twisting, penetrant in mercerizing, wetting-out for flameproofing, carbonizing assistant, assistant to fulling soaps and in acid fulling, penetrant in rayon manufacture, and desulfurizing and cleansing of spinnerets, etc.

There exists a great deal of confusion in defining "wetting agents." Strictly speaking, they are those surface-active agents used to lower interfacial tension between solids and water and thus to reduce the contact angle between the water and the material to be wet. They of course also lower surface tension or the interfacial tension between water and air.

When wetting agents possess other properties in addition to these they are no longer, strictly speaking, wetting agents and should be classified as suspending agents, protective colloids, emulsifying agents, or synthetic detergents. For instance, when they possess a gel-like structure or are used in conjunction with glue to increase the viscosity of the water phase, they become suspending agents and are used to keep finely divided solids from settling out.

The chemistry of the elementary or straight wetting agents, typified, for instance, by the alkyl naphthalene sodium sulfonates or poly-carboxylic acid ester sulfonates, is today quite well known and represents the field in which research has come closer to the textile industry. Wetting agents were originally developed by and for the textile industry but have found many other uses in other industries. This is the reason for the vast literature on these products.

Wetting agents are usually heteropolar molecules possessing a balance between a hydrophobic or hydrocarbon chain and a hydrophilic or polar grouping, the latter imparting the water-solubility. These molecules orient at the interface and give the desired results.

It is usual in the textile industry to classify surface-active agents in general into three groups according to their ionic character, as follows: anion-active, cation-active, and non-ionic. Stability of the compound to acid and alkaline baths, as well as to hard water, is necessary in the majority of textile operations. There are, however, many uses for compounds not possessing these three advantages. The first gap in the field of the wetting agents is the lack of an agent which will perform its function during the required operation and which will become ineffective after drying. Such a product would have use in the application of water-repellent finishes. At present there is one type of product on the market which will act as a wetting agent and when dried will not cause rewetting of the fiber. This lack of rewetting, however, is possibly due to its slow solubility and not to decomposition. It still remains in the fiber and eventually will function as a surface-active agent on prolonged contact.

The chemistry of the rewetting agents is almost nil. There are few of them and all are elementary wetting agents and not synthetic detergents; in other words, they do not possess emulsifying and other properties in addition to the pure wetting properties. Examples are the sulfonated esters of carboxylic acids mentioned previously.

Synthetic Detergents

These products were developed for the textile industry mainly by the dye industry, which endeavored successfully to offset the disadvantage of soap—namely, poor acid and hard-water stability—by introducing sulfonated fatty acids, and later the entire synthetic detergent line; that is, the sulfonated fatty acid amides, alkyl aryl sodium sulfonates, sulfated fatty alcohols, etc. These products were not developed originally as soap substitutes, excepting for the textile industry.

Where soap's shortcomings are evident there is no question concerning the value of synthetic detergents. However, where soap is used under optimum conditions there is still much to be desired in the properties of the pure synthetics. This differentiation unfortunately has not been strictly adhered to, and commercial advertising has attempted to indicate that synthetic detergents are superior to soap under all conditions. Were this the case, there would not be such a host of patents dealing with methods for increasing viscosity and lowering solubility in an endeavor to closely approximate soap characteristics. It is interesting that the first synthetic detergent developed to take the place of soap in the textile industry is still the one which satisfactorily competes with soap in borderline usage. The term "borderline usage" applies to water conditions of medium hardness.

Soap itself possesses good wetting properties, particularly in the case of the more soluble medium-length carbon chains (8–12 carbon atoms), unsaturated fatty acids, branched chains, and also those containing hydroxyl groups on the chain portion. The properties of soap therefore vary greatly. It is well known in the industry that the higher titer soaps scour better but are not readily removable, particularly at low temperatures. These higher titer soaps form heavy gels on cooling, and this is the property which few of the synthetic detergents possess and which the textile industry classifies as "body," "soil-removing properties," "heavy duty," etc. The strong solubilizing $NaSO_3$ group, which is present in the synthetic detergents and which imparts the quick solubility and ease of rinsability to the molecule, apparently acts in reverse when it comes to fulling properties and soil removal under difficult loads. The use of synthetic detergents to facilitate fulling operations is still one of increasing the stability to the rinsing of soap and is not in other ways a direct contribution to fulling.

The peculiar functioning of the synthetic detergents in wool scouring, in which they can easily compete with soap providing the system of wool scouring is modified somewhat, has not as yet been explained.

These remarks are intended to cover the sulfonated fatty acid esters, the true sulfonated fatty acids, the sulfated fatty alcohols, alkyl aryl sulfonates, sulfonated fatty acid amides, and ethylene oxide polymers, all of which are true synthetic detergents possessing true scouring properties. They are anion-active materials, with the exception of the last, which is non-ionic.

The cation-active surface-active agents possessing scouring properties are quarternary ammonium salts,

such as octa-decenylamide N-ethyl amine hydrochloride $CH_3(CH_2)_7CH=CH(CH_3)\cdot CO\cdot NHC_2H_4NH_2\cdot HCl$. None of the cation-active detergents have approached the sulfonated or the non-ionic types. They are, furthermore, limited by the fact that they function best on the acid side. They are likely to form scum because they react with anion-active materials, which constitute approximately 99 percent of the chemicals used in dyeing and finishing operations, and, furthermore, they reduce the light-fastness of dyes.

Light-fastness is another phenomenon, the secret of which has not been found and possibly not yet satisfactorily explained.

Synthetic detergents, besides performing as satisfactory kier boiling compounds, desizing agents (action not biological, of course), have uses in the level dyeing of all types of dyes. Those possessing sulfonic polar groupings have proved the best for wool dyeing because of the chemical reactions involved. The long-chain structures, however, are inferior to those of the flatter molecules. Sulfonated types when used in direct color dyeing seem to assist primarily by permitting the dyes to wet easily and quickly at the beginning of the dyeing process. These products are, of course, not of any value in basic color dyeing, which must be assisted by cation-active or non-ionic types. The non-ionic types of compound are good for direct color dyeing. When the detergent properties are reduced an even greater improvement is noted.

The indiscriminate use of all surface-active agents in many textile operations can cause a great deal of trouble. At times detergent properties are a hindrance—for instance, in the padding of dyes. At times excessive foam is objectionable. There are many cases in which the pure wetting agent is the only one which will perform satisfactorily, and there are other cases in which the dispersing agent or the detergent with poorer wetting properties is more suitable. The textile industry is well aware of these conditions and is demanding more information concerning chemical constitution of products and newer, better products.

During the past few years, when the nation's efforts have been concentrated on the service of the armed forces, there have been numerous instances in which the application of wetting agents and synthetic detergents have enabled great speed-up of production in bleaching, dyeing, and printing operations.

Streamlining of plant equipment and operations is also calling more and more for surface-active agents.

Finishing of Fabrics

The first two groups of compounds discussed have a place in finishing operations which are, strictly speaking, those operations which are performed on a fabric to enhance its feel and eye appeal, to impart greater wearability, and to produce the properties outlined at the beginning of this paper. Finishing operations will be called upon more and more to solve the intricate and scientific developments of the industry. Mildewproofing, which has been one of the paramount requirements for jungle warfare which requires vast quantities of ducks, canvas, and tenting, has been attained by the introduction of fungicides capable of protecting these fabrics in the intense heat and humidity of the jungles. Large amounts of chemicals have been developed for this purpose, and it is expected that civilian needs for these for awnings and garden furniture will increase.

At one time starch constituted the main chemical ingredient of all finishes. Mechanical operations such as calendering, tentering, breaking, etc., did the rest. The housewife expected that her dress or fabric would lose its new appearance on the first light washing. Nowadays the trend is toward permanency of finishing. If the fabric has a glaze it must be permanent; if it is waterproofed or flameproofed this effect must be permanent; and so on. Resins, particularly those of the urea-formaldehyde types, have found their place at last in the spun rayon field, imparting crush-resistance, non-slip characteristics, and fabric shrinkage control. They also are successfully employed in the permanent glazing of cotton fabrics (chintz).

Flameproofing of materials for use in the theater is practical, but a stable wash-fast effect is still being sought. Here is a problem that the textile industry has not been able to solve even though a great many organizations have devoted considerable time to it. What is desired is a flameproof finish which will not interfere with the porosity and feel of fabric and yet be fast to washing. The present types of flameproofing compounds are ammonium salts, which are very readily water-soluble. The common method for treated tenting fabrics is the anchoring of an inert pigment, such as antimony oxide, with a binding

agent, which unfortunately imparts too firm a finish and interferes with the porosity of the fabric.

Acid fading of acetate on fabrics is under control as far as the storage of these fabrics is concerned, but research must concentrate on a wash-fast type of this finish which will give protection during the entire life of a garment.

Permanently mothproofed wool can be purchased, and this is an achievement of real value. Materials used to impart soft, drapey qualities to fabrics are still not fast to washing. One material which is fast to washing, the fatty acid pyridinium type, imparts water-repellent properties and thus defeats its purpose when water-repellency is not desired. The textile industry cannot afford to use intricate chemical processing, involving curing or polymerizing operations followed by neutralization and washing. To be of real value products should be adapted to a one-bath operation, followed by drying. Here it seems appropriate to say that solvent applications should one day find their way into the textile industry as they have found their way into the vast dry-cleaning industry. Does it seem logical that fabrics which are to be washed should not be dyed or finished with water-soluble compounds? Would it not be easier to apply solvent-soluble compounds and recover the solvent by suitable mechanical means?

In the field of water repellents the greatest progress has been made in a permanent type involving reaction of stearoyl oxymethyl pyridinium chloride or similar products with the fiber. Some literature has appeared on the possible chemical combination of this material with cellulose. We sometimes wonder why, if this is true, other compounds to impart flame-resistance, antisepsis, shrinkage control, and permanent finishing are not developed.

The use of permanent cellulose finishes to impart stabilized finish to nettings has come into its own during the war. Better fabrics with wash-fast crispness, fullness of hand, and shrinkage control are therefore promised for the post-war period. However, the drastic chemical treatment—caustic soda solutions followed by sulfuric acid and washing—required by these is certainly not a streamlined development. Can similar effects be obtained by resins without the lengthy curing treatment?

A permanent cellulose finish is one whose characteristics are due either to producing a change in the cellulose of the textile itself or to the addition of cellulose or modified cellulosic material. Such a finish should not be materially removed or its characteristics modified or changed by laundering or dry-cleaning.

The foregoing definition indicates that there are two groups of finishes, the first of which is produced by processes that modify or change the characteristic of the cellulose of the textile, such as mercerization, the Heberlein, and the cuprammonium processes. The second group is produced with viscose solutions, cuprammonium solutions of cellulose, caustic solutions of cellulose ethers, and the more recent catalytical activated caustic solutions of cellulose. All of these will yield a permanent finish.

Such finishes have been applied to a fabric used for interlining apparel for aviators and for troops in cold climates. It was designed primarily as a substitute for sheepskin linings. Sheepskins have great warmth but are also very cumbersome and do not allow complete freedom of body movement. The above-mentioned fabric has great flexibility and does not encumber the wearer.

Nowadays every soldier in the U. S. Army has a windbreaker made of a cotton poplin with a permanent water-repellent finish.

Millions of yards of fabric used by the U. S. Army for tenting, truck covers, pontoons, stretchers, haversacks, boots, and a host of other articles have been given a water-repellent, mildewproof treatment.

A light cotton fabric used by the Army for sleeping bags has been given a mildew-repellent plus water-repellent finish and can therefore be used in contact with the ground without mildewing or rotting.

For stretcher cloth it is important that the repellents be non-toxic and non-irritant to the skin. Otherwise, contact with wounds would be disastrous.

A fabric with a bright rayon surface and cotton back is used for officers' raincoats. Semidurable repellents are used to give fast-to-dry-cleaning, fast-to-washing effects. The garments made from it are worn with the shiny side in. The fabric is also used by parachute troops, for the smooth surface allows the parachuters to slide into them readily. When worn on parade they are reversed, with a striking effect.

None of these would have been possible without the development of an industry which ran parallel to that of the application of dyes.

An O.D. herringbone twill used for fatigue uni-

forms is given water-repellent finish and is used for work clothes.

There is another field of application of compounds which is of interest. The Army and Navy require soaps which can be used in any water in any location, including salt water. Ordinary soap is not suitable and will not foam or clean in salt water. A solution consisting of 50/50 soap and synthetic, which can be used to scour in salt water or any other water, has been used in large quantities by the Navy, in laundries, and for personal use, as well as for cleaning ships' decks and painted surfaces.

Mechanization of Cotton Production in the Mississippi Delta: Its Relation to Cotton Quality and Marketing Practices

Francis L. Gerdes

Stoneville Laboratory, Office of Marketing Services, U. S. Department of Agriculture

COTTON production has been tending toward mechanization for a long time; and in recent years considerable impetus has been given to this development by machinery manufacturers, wide-awake cotton producers, and research workers. The labor shortage and the realization on the part of many agricultural leaders that mechanization offers at least a partial solution to our cotton problem are the chief factors bringing about further advancements in the mechanization of cotton production. Moreover, relatively large acreages of comparatively level and fertile lands, developed to a point of high productivity through improved soil-management practices and planting of high-yielding varieties of cotton, are lending themselves readily to complete mechanization. Research and improvement programs with respect to breeding, ginning, and marketing have yielded information, which, when applied in practical operations over wide areas, also furthers the success of mechanized farming. It appears likely that mechanization will expedite the adoption of revolutionary methods that are in sight for ginning and marketing as a result of the information being derived from cotton-quality research and testing programs.

The Mississippi Delta is ideally suited for making practical use of basic information, whether for improvement in producing, ginning, or marketing practices. The cotton acreage during the past 3 years in the Delta has averaged about one million acres, as compared with an average of over one and a half million acres during the period 1930–1932. On an acreage reduced by one-third, the total production has been increased by over 45 percent. The production now is substantially higher on the reduced acreage than it was prior to the reduction program because of the marked increases in yield per acre. These increases are attributable to better selection of cotton land, use of better land-preparation methods, adoption of improved soil-fertility practices, and increased planting of the more productive varieties of cotton. Production per acre in the Delta during the past 3 years averaged almost 450 pounds, or nearly a bale per acre, as compared with less than 200 pounds during the 3-year period which ended in 1932. During the past season, 14 mechanical pickers were employed on 6 plantations in the harvesting of more than 2,000 bales of cotton in the Delta. Indications are that these machines are technically and economically feasible, and highly adaptable to farming operations in the Delta.

Check-row planting and cross-plowing practices have been followed for a number of years by some of the larger plantation operators to eliminate chopping by hand, and to reduce to a great extent the cost of subsequent hoeing for grass and weed con-

---

Condensation of a paper delivered at the Cotton Research Congress, Dallas, Texas, July 12, 1945.

trol. Flame cultivation for controlling grass and weeds was used by growers in the Delta for the first time last season and was found to have great promise as a means for further reducing hand labor in hoeing and chopping. It is estimated that approximately 50 mechanical pickers will be used in the Delta next fall. Thousands of acres of cotton were cross-plowed last spring. Flame cultivators are now in use on virtually all plantations that will operate mechanical pickers in the fall. Moreover, extensive improvements have been made in the ginning plants that will handle the machine-picked cotton.

Special attention will be given to determine the cotton varieties best adapted to machine picking. The complete success of the mechanical cotton picker depends upon the solution of problems involved in providing improved grades of cotton. Various means for their solution may be grouped in three principal categories, as follows: (1) the development of varieties of cotton possessing growth and fruiting characteristics especially adapted to harvesting with mechanical pickers; (2) induced defoliation of the cotton plants prior to harvesting in order to facilitate machine harvesting and to reduce the amount of extraneous matter in the seed cotton; and (3) the development of more effective equipment at gins for the conditioning and cleaning of seed cotton harvested mechanically. Progress is being made on these items, and cotton breeders are already taking into consideration in their breeding efforts properties of the plant and fibers that are conducive to providing desirable grades for cotton harvested mechanically.

Defoliation of the cotton plant at picking time is held out as another promising way of facilitating mechanical picking and at the same time of reducing the amount of extraneous matter in the seed cotton. There is also the benefit of more timely harvesting of cotton with a machine over delayed hand picking.

However, in spite of the benefits that may be obtained from breeding cotton better adapted to machine picking, the use of defoliants to induce leaf shedding, and the reduction in fiber and cottonseed deterioration through the more timely use of the machine before excessive weather damage to the cotton, the development of efficient cleaning machinery for use at gins is the most important key to the success of cotton-production mechanization. In view of the results being obtained in cleaning machine-picked cotton, there is a rather general conclusion on the part of those concerned with the development of suitable equipment for cleaning this cotton that principles of cleaning, radically different from those employed in cleaning hand-picked and snapped cottons, are needed to provide effective means for cleaning mechanically picked cotton. In the final analysis, successful adaptation of mechanical harvesting to the American cotton crop is likely to depend upon the development of equipment for the economical and satisfactory extraction of extraneous matter from the ginned lint after its separation from the seed and before it is pressed into bales at the gins.

Research directed to the development of equipment to accomplish this purpose is now under way in connection with the investigations of the U. S. Cotton Ginning Laboratory. Cotton manufacturers are reported to be following these developments in connection with cotton production mechanization, and much of the machine-picked cotton was tested by interested manufacturers last season with gratifying results, considering the discounts at which the cotton was purchased.

Manufacturers recognize that production mechanization, to be completely successful, must be practiced on a large scale. It will be a factor in expediting the production of one variety of cotton in quantities sufficient to attract the attention of agents of textile mills, some of whom now recognize the advantages of pure-variety cotton lots over mixed-variety lots. Producers who have made advances in mechanized farming realize that the production of a variety of cotton highly acceptable from a spinning standpoint is imperative and will have an important place in a cotton-production mechanization program.

ABSTRACTS

SERVICES AVAILABLE

Reprints of the original articles abstracted in TEXTILE RESEARCH JOURNAL *are often available from the publishers. Otherwise, it may be possible to secure copies of the periodicals. A list of periodicals, the abbreviations used in references to articles, and the addresses of publishers of English language publications was given on page 22 of the January, 1945, issue. Orders should be sent direct to the publishers.*

Photostat negatives of articles abstracted will be furnished to members of the Institute at a cost of 15 cents per page for pages not exceeding 7 inches in width and 25 cents per page for larger sizes up to 11½ x 14 inches. Photostats of patents are 25 cents a page. Postage will be added.

Microfilm copies and paper enlargements of microfilm may be obtained from: Microfilms Inc., 313 N. First St., Ann Arbor, Mich.; New York Public Library, New York, N. Y.; Yale University Library, New Haven, Conn.; Harvard University Library, Cambridge, Mass.; and Library of Congress, Washington, D. C. Translations may also be obtained from the above sources.

ANALYSIS: TESTING: LABORATORY METHODS

★

Acetate Buffer Solutions

A nomogram for acetate buffers. William C. Boyd. *J. Am. Chem. Soc.* **67**, 1035–6 (June 1945).

The nomograph given enables buffer mixtures to be made up of sodium acetate and acetic acid varying in ionic strength from 0.005 to 1.50 and of pH varying from 3.5 to 6.0.

A. R. Macormac

Estimation of Cellulose

$NaClO_2$ as a reagent for the estimation of cellulose. P. B. Sarkar and H. Chatterjee. *Science and Culture* **10**, 340–2 (1945) (through *Chem. Abstr.* **39**, 2871[1] (July 10, 1945)).

The authors propose a new method of determining fiber cellulose (α-cellulose and hemicellulose) in jute, based on the action of $NaClO_2$ (**I**) in acid solution. Two g. of finely cut jute, defatted with alcohol-C_6H_6, is treated for 4 hrs. at 60–90° with a 3.5% solution of **I** and maintained at pH 4–5 by glacial AcOH. Suspension is then filtered through a glass filter crucible (Jena $1G_3$), washed with cold H_2O until free from **I** (starch-iodide test), treated with 3% $NaHSO_3$ and again thoroughly washed. The crucible is dried in a water bath under reduced pressure to avoid appearance of yellow color. In a sample of jute, cellulose + lignin total by this method 100.83; by Cross and Bevan, 84.35; by ClO_2, 96.76; by Norman and Jenkins 89.57%.

Extensometer

Cambridge textile extensometer. Anon. *Indian Text. J.* **55**, 333–4 (Feb. 1945).

An illustrated description is given of an instrument for testing and recording the load-elongation characteristics of textile fibers, yarns, and threads having breaking loads up to about 3 lbs. Measurements can be made with increasing and decreasing loads. If necessary, the test specimen can be immersed in a liquid or in a box containing air with a known humidity. The instrument can be operated at a constant rate of loading or a constant rate of extension of the specimen, as desired. Records are made on rectangular coordinates.

R. K. Worner

New Type Fungus Found to Attack Cotton

A new species of Metarrhizium active in decomposing cellulose. S. Pope. *Mycologia* **36**, 343–50 (1944); *Rev. Applied Mycol.* **23**, 494 (through *Chem. Abstr.* **39**, 2647[5] (June 20, 1945)).

A fungus, which is named *Metarrhizium glutinosum*, was isolated from deteriorated baled cotton in Washington, D. C., and was found to have extraordinary activity in decomposing cotton fabric. It has been used in the evaluation of mildewproofing agents and the resistance of fabrics to rotting. It is easily handled in culture, sporulates freely, and has remained stable in its cultural characteristics and cellulose-decomposing activity for three years.

Rot-Proofed Fabric Testing

The soil burial test for rot-proofed cotton fabrics. J. D. Dean, W. B. Strickland, and W. N. Berard. *Am. Dyestuff Reptr.* **34**, 195–201 (May 7, 1945).

If untreated cotton cloth of medium weight is buried to a depth of a few inches in any natural soil capable of supporting plant growth it will lose most of its strength in 6 or 7 days; if the same cloth is treated with a good rot-proofing compound its life under identical conditions will be extended to 6 or 7 weeks. The results of extensive experience in the use of soil burial for determining rot resistance of textile fabrics, and the development of certain standard methods in carrying out this type of test are described. It was found that horizontal burial of fabric strips in indoor thermostatically controlled beds of freshly prepared composted soil (equal parts of fertile topsoil, sand, and well-rotted stable manure) kept at a moisture content of 30% and at 85° F, was required in order to approach reproducibility of test results. A standard treated control fabric is included in each test set in order to provide a common basis on which to judge the rot resistance of different treatments; the rotting characteristics of the standard treated fabric (copper naphthenate applied to cotton osnaburg from solvent solution so as to give 1% Cu

on the weight of the cloth) were determined by a series of tests in which 42 days' burial was established as the average time required to produce a breaking strength loss of 80% in this fabric; the time in days figured on this basis is called the "resistance number" of a given fabric. In running a soil-burial test any marked departure from normal in control fabric performance indicates that testing conditions are unreliable and the determination should be repeated. Data so far available from performance tests on cotton sandbags show that treatments which have consistently shown high resistance numbers in soil-burial tests make the best records in service performance.) K. S. Campbell

Sliver Tester

Condensed charts for sliver tester. C. H. Plummer. TEXTILE RESEARCH JOURNAL **15**, 10–14 (Jan. 1945).

Certain modifications on the Saco-Lowell sliver tester made by Chicopee Manufacturing Corp. are discussed. Additional gearing provides for ratios of 144 : 1 and 1728 : 1. Therefore, the slowest chart speed condenses the record of 1,728 yds. of sliver on to 1 yd. of chart. These changes make it possible to represent the characteristics of a complete can of sliver utilizing the 1728 : 1 chart speed ratio in this length and permit analyzing changes in linear density taking place throughout whole cans of sliver as well as in shorter lengths. Typical charts are illustrated. J.

CHEMICAL AND PHYSICAL RESEARCH

★

Abrasion Mechanics

Mechanics of abrasion of textile materials. Walter J. Hamburger. TEXTILE RESEARCH JOURNAL **15**, 169–77 (May 1945).

A method is described for predicting the inherent abrasion resistance of textile materials substantively by the use of load-elongation diagrams of mechanically conditioned specimens. Immediate and delayed deflections are discussed as they affect energy coefficient E. This coefficient is shown to be a function of: (1) low modulus of elasticity, (2) large immediate elastic deflection, (3) high ratio of primary to secondary creep, (4) high magnitude of primary creep, and (5) high rate of primary creep. Nylon shrunk, nylon unshrunk, acetate, and viscose yarns are evaluated on the Taber Abraser, and from rate-of-destruction curves durability coefficients D are obtained. Correlation is shown to exist between durability coefficients and energy coefficients for the four yarns. Author

Relativity of Cellulose

The manner in which native cellulose reacts: I—Fiber structure as a retardant of cellulose reactions. Richard Bartunek. *Cellulosechem.* **22**, 56–63 (1944) (through *Chem. Abstr.* **39**, 2401⁴, June 10, 1945).

Based on laboratory and industrial experiments, the hypothesis is advanced that, as the result of the stratified fibrillar and fine structure of cellulose, diffusion processes are retarded. In viscose formation, mercerization is retarded because the aqueous NaOH solution, as it penetrates the fiber, becomes reduced in strength. Xanthate formation is slowed down because of the difficulty of CS_2 diffusion, and the treated fiber dissolves only when the swelling pressure within the fiber layers is sufficiently great to rupture those outer layers which swell very little or not at all. In testing fibrous materials, B. has devised rapid practical control methods, which are described in detail. The "lignin no." depends on the treatment of the fiber with 13% HNO_3 at 40° and the effecting of a colorimetric comparison of the yellow color (resulting from dissolved lignin derivatives) with a standard solution of $K_2Cr_2O_7$ and $KMnO_4$. An arbitrary color scale is developed in this way; if a color value of 1 is assumed for an ordinary bleached pulp, dissolving pulps have a lignin-no. range of 0.02–0.3. The degree of bleaching of a pulp may be measured in terms of a carefully standardized microscopic staining reaction with malachite green. Similarly "carbolated-gentian violet" (von Fram's stain), which is fixed by acid groups of the fiber, serves as a measure of the—CO_2H groups and of the degree of injury due to oxidation. Xanthate viscosity and degree of polymerization were determined by a standardized laboratory xanthation procedure which is described in detail. The so-called "resistance to mercerization" (I) of a pulp is determined by treating the pulp under standardized conditions with a solution of NaOH (85 g./l.) in an amount insufficient to complete the mercerization. The partially formed alkali cellulose is then treated with a large excess of CS_2 and the fibrous residue which remains insoluble in NaOH is separated by centrifuging and by washing with aqueous NaOH, dilute HCl, dilute NH_4OH, and H_2O, dried and weighed. Thus I is given in terms of percentage of undissolved fiber based on the original pulp. "Resistance to xanthation" (II) of a pulp is determined by treating with sufficient (200 g./l.) aqueous NaOH to insure complete mercerization but with insufficient CS_2 to give complete xanthation. The unattacked fibrous residue is treated with 100 g./l. NaOH, and is separated as described for I. The "resistance toward viscose formation" for a pulp is the average of I and II. The influence of the hemicellulose content of alkalin steeping liquors on the magnitude of I was also determined. Data are given for 2 common spruce and 1 beech sulfite pulp. In general I (as determined by using pure NaOH) showed an increase when alkalin steeping liquors containing hemicelluloses were used. Correlations between degree of polymerization and II for the pulps are shown graphically and discussed.

Viscosity of Cellulose Derivatives

The viscosity of dilute solutions of nitrocelluloses derived from chemically modified cotton celluloses of various types. T. Brownsett and G. F. Davidson. *J. Text. Inst.* **36**, T1–9 (Jan. 1945).

The relations between the viscosity

and the concentration of acetone solutions of nitrocelluloses derived from hydrocelluloses, dichromate oxycelluloses, and periodic acid oxycelluloses, have been investigated over the concentration range 0–0.25%. The viscosity-concentration relation is not the same for the derivatives of all three types of modified cotton cellulose. If, at a very low standard concentration, a nitrated hydrocellulose has the same relative viscosity as a cellulose nitrated after oxidation with periodic acid, the relative viscosities of the two products are not the same at a higher concentration, the derivative of the oxidized cellulose then having a greater viscosity than the derivative of the hydrolyzed cellulose. As an explanation of this result, it is suggested that the degree of association of nitrocellulose molecules of a given average chain-length, and hence the viscosity at a finite concentration, is influenced by chemical changes—other than depolymerization—resulting from the oxidation of the cellulose with periodic acid. When dichromate is the oxidant, there is only a slight difference between the viscosity-concentration relations for the nitrated oxy- and hydro-celluloses. The relation between viscosity and concentration for all three types of nitrocellulose is satisfactorily represented by the equation $\log (\eta_{sp}/c) = \log (\eta) + mc$, where η_{sp} is the specific viscosity, c is the concentration, (η) is the intrinsic viscosity, and m is a constant. The qualitative behavior recorded above is expressed formally by the fact that within a series of nitrocelluloses derived from a given type of modified cellulose m increases with (η), but the relation between m and (η) varies from one type of modified cellulose to another. In support of the suggestion that oxidation of cellulose with periodic acid leads to nitrocelluloses of relatively high degree of association in acetone solution, it is shown that under certain conditions the progressive oxidation of a cellulose material with periodic acid results in a progressive rise in the viscosity of the derived nitrocelluloses. Author

Cellulose Xanthate

The story of modern textile fibers: 13—Viscose rayon. Anon. *Silk and Rayon* **19**, 199–201 (Feb. 1945).

In the sulfiding reaction to form cellulose xanthate from alkali-cellulose produced by treating cellulose with 16–20% caustic soda, there should be at least 2 molecules of NaOH and 1 molecule of CS_2. It was found that the most stable solutions of cellulose zanthate were those which contained about 8% of caustic soda, and these solutions had the lowest viscosities in the early stages of storage; this and related data are illustrated graphically. Changes that are connected with the state of the cellulose in the viscose solution may be followed by analysis of cellulose xanthate isolated by ethyl alcohol or acetic acid. Low percentages of carbon bisulfide result in a cellulose xanthate which is difficult to completely dissolve; on the other hand, high percentages form by-products that decrease the stability of the viscose solution. There is considerable degradation of the cellulose during xanthation but scarcely any in the ripening process which follows. A. L. Merrifield

Physics of Crystals

Fundamentals of crystal physics. C. V. Raman. *Current Sci.* **12**, 342–4 (1943) (through *Chem. Abstr.* **39**, 2238⁹, June 10, 1945).

An address.

Acids of Degras

The acidic constituents of degras: A new method of structure elucidation. A. W. Weitkamp. *J. Am. Chem. Soc.* **67**, 447–54 (Mar. 1945).

The acidic constituents of the sterol esters in a sample of commercial degras were found to belong to four series of fatty acids: first, 9 normal even carbon atom acids C_{10} to C_{26}; second, 2 optically active 2-hydroxy acids C_{14} and C_{16}; third, 10 iso- even carbon atom acids C_{10} to C_{28}; fourth, 11 dextro-rotatory anteiso odd carbon atom acids C_9 to C_{27} and C_{31}. The anteiso acids are defined as branched chain acid with a methyl group on the third carbon atom from the end. The acids were identified by mixed melting points, crystal structure, etc. A new method for the determination of the structure of acid or amides with a methyl side chain is based on the number of transitions in the solidification-point curve of binary mixtures of the branched and normal compounds. A. R. Macormac

Fabric Deterioration

Fabric deterioration by thirteen described and three new species of *Chaetomium*. Glenn A. Greathouse and L. M. Ames. TEXTILE RESEARCH JOURNAL **15**, 223–5 (June 1945).

Few studies have been made to determine the importance of species of cellulose-decomposing organisms other than *C. globosum Kunze*. Evidence is presented in this paper which establishes the comparative abilities under similar experimental conditions of 16 species of *Chaetomium* to decompose cotton fabric. Drawings of most of the species are shown. J

Microscopy of Fiber Cell Wall Structure

Applications of nitrogen dioxide treatment to the microscopy of fiber cell wall structure. Mary L. Rollins. TEXTILE RESEARCH JOURNAL **15**, 65–77 (Mar. 1945) (through *Chem. Abstr.* **39**, 2653 (June 10, 1945)).

NO_2 pretreatment is a new technique for the microscopical study of fiber structure by swelling. Fibers so treated were observed during swelling with lyo-tropic reagents to study cell-wall structure. The fiber sheath (primary wall and "winding layer") split into fine fibrils or into broad spiral bands, depending on the degree of NO_2 oxidation. Reversals are observed in the fiber sheath. The fiber sheath appears to have a banded structure when not ruptured by swelling of the cellulose beneath it. No spiral structure was observed in any layer of the secondary

wall of cotton below the inner sheath, but the lamellae of the secondary wall seemed to disintegrate into fine fibrils which lie more or less parallel with the fiber axis. Spiral fibrils were observed in the secondary wall layers of NO_2-treated ramie fibers and milkweed bast fibers, but the angle of their spiral orientation with respect to the fiber axis is several times greater than the slight angle of orientation seen in x-ray diffraction patterns. The spiral angle in the primary wall also varies with the degree of swelling: that for a ramie fiber varying from 28 to 45 degrees and for a flax fiber from 37 to 44 degrees. 43 references.

Morphological Research

Swelling of fibers as a method for morphological research. Bruno R. Roberts. TEXTILE RESEARCH JOURNAL **15**, 46–53 (Feb. 1945).

The application of cinemicrography to the dark-field ultramicroscopy of textile fibers permits repeated and close observation of the rapidly changing movements of colloidal inclusions energized by suitable swelling agents. Through this technique the permeable membranes of starch particles and natural fibers are made visible. The effects of osmotic pressure, such as the instantaneous eruption of colloidal masses from the ruptured envelope of starch grains and cotton fibers, have been recorded by the motion picture camera and thus made available for careful study. The inhomogeneity of wool scales and their capsule-like structure are recorded. The movement of colloidal particles within and through the outer walls of the swollen cotton fiber has been photographed and it can be analyzed at leisure by projecting the film. The effects are illustrated by photographs of sections of film. J.

Gels in Addition Polymer

Gel formation in addition polymerization. Cheves Walling. *J. Am. Chem. Soc.* **67** 441–7 (Mar. 1945).

Following the statistical method of Flory, an equation has been developed for predicting the gel point in the addition polymerization of mono- and bifunctional monomers. Gel points for the systems methyl methacrylate-ethylene dimethacrylate and vinyl acetate-divinyl adipate were determined. Results are in reasonable agreement with the equation only in the presence of small amounts (less than 0.2 mole %) of the bifunctional monomer. Discrepancies are explained on the basis of the presence of discrete swollen polymer molecules whose diffusion rate is slow in comparison with the rate of growth of the polymer chain. A. R. Macormac

Chemistry of Soap Solutions

Effect of sodium hydroxide on dissolved soap. Chester A. Snell, Benjamin P. Caldwell, Foster Dee Snell, and L. C. Cartwright. *Soap and Sanitary Chemicals* **21**, 42–3, 78 (Mar. 1945).

When NaOH is added to 0.1% sodium oleate solution, the dissociation is repressed as shown by a decrease in the apparent conductance of the soap, and further micelle formation takes place. The solution becomes increasingly opaque as the NaOH concentration increases until a "salting out" effect gives a flocculent suspension. Decreased ionization and increased micelle formation appear to be more likely to take place at lower concentrations of NaOH, followed by sorption at higher concentrations.

E. G. Martin

Effect of Air on Viscose

Effect of 0 of the air on viscose. Olof Samuelson. *Svensk Papperstidn.* **47**, 597–601 (1944) (through *Chem. Abstr.* **39**, 2402[1], June 10, 1945).

According to earlier investigations, cellulose (*I*) in viscose (*II*) is not decomposed when exposed to the 0 of the air. The present work presents evidence which shows that intimate contact between *II* and air might cause considerable oxidative degradation. The decomposition was followed by viscosity measurements of the *II* and of the *I* regenerated from it. In the latter case, the determinations were carried out in highly diluted solutions (determination of degree of polymerization according to Staudinger), with either cuprammonium solution or butyl acetate after the nitration of the hydrated *I*. The degradation could not be traced to catalytic effects of metal salts. Attempts to prevent the action of atmosphere 0 by the addition of glucose and sulfite failed. When preparing *II* on a laboratory scale, the influence of the atmosphere 0 is suitably eliminated by dissolving the xanthate in an atmosphere of N. This will increase the reproducibility of the viscosity tests and the filtration. On a mill scale, the common procedure of dissolving the xanthate in large quantities in the usual equipment will probably prevent any serious degradation. However, since attempts are being made to improve the properties of *II* by intensified mechanical treatment, it is not impossible that a stage may be reached where the dissolving of the xanthate in a N atmosphere will become necessary to exclude the harmful effects of atmosphere 0.

Birefringence of Macromolecules

Flow birefringence in solutions of macromolecular substances. J. J. Hermans. *Rec. trav. chim.* **63**, 25–31 (1944) (in German) (through *Chem. Abstr.* **39**, 2242[7], June 10, 1945).

Equations obtained previously (cf. *C.A.* **39**, 659[4]) give values that agree satisfactorily with experiments described in the literature. The experimental evidence supports the model of flexible, randomly kinked molecules. Curves are given for antipolysaccharide, citrus pectin, and nitrocellulose in butyl acetate and cyclohexanone solutions.

Infra-Red Scattering by Macromolecules

Macromolecules and their relation to infra-red radiation. I. Plotnikov. *Phot. Korr.* **79**, 40–5 (1943); *Chem. Zentr.* **1943**, **II**,

1265–6 (through *Chem. Abstr.* **39**, 2242², June 10, 1945).

When light is passed through a turbid medium of filamentous chain molecules, scattering occurs which is different from the Tyndall effect. A conical spreading of the parallel rays takes place which cannot be observed from the side and which appears on the photographic plate in the form of an aureole. Objects photographed through such a medium, therefore, are not sharp. This phenomenon is designated as longitudinal scattering of light. The possibility of explaining the structure of high-molecular compounds by an investigation of such longitudinal scattering is discussed.

Hysteresis in Viscous Systems

Structure mechanics of viscous elastic systems: IX—Hysteresis in viscous systems. H. Umstätter. *Kolloid-Z.* **105**, 182–90 (1943); cf. *C.A.* **38**, 1161⁴ (through *Chem. Abstr.* **39**, 2241⁸, June 10, 1945).

Space diagrams are given based on the Maxwell equation to show the change in shearing stress and viscosity with changing velocity gradient and relaxation time. The flow curves show that the results obtained for the middle range of shearing stress are less reliable than those for very high or low stresses. This is due to a hysteresis phenomenon and not to inaccuracies of the measuring methods. The space diagrams indicate that the hysteresis loops are characterized by the lack of residual viscosity (thixotropy) and the lack of coercive force (yield value) which can occur only in case of liquids. The hysteresis loops of solids show in the stress-strain diagram a permanent deformation and have a definite yield value (flow strength). The fundamental property of matter from a structure-mechanism viewpoint can be derived from 3 basic constants: the shearing elasticity, time of relaxation, and the minimum thickness of layers. **X—Shear-stress diagrams.** *Ibid.* **107**, 81–6 (1944).—By integration of Newton's viscosity equation it is possible to arrive at a stress-time function that can be utilized for elastic shear deformations. Space diagrams are given for typical materials such as metal, rubber, and rayon, based on the stress-shear-time of relaxation equation. Viscous elastic solid bodies show a residual shearing and a coercive shearing stress. The shear-stress equation permits an accurate definition of plasticity.

FIBERS: YARNS: FABRICS: MECHANICAL PROCESSES

★

Cellulose Acetate Yarn

Cellulose acetate yarn. A Chem. and Met. Flow Sheet. Anon. *Chem. and Met. Eng.* **52**, 132–5 (Jan. 1945).

A flow sheet describes the preparation of cellulose acetate and its fabrication into yearn. Twelve photographs from the Meadville, Pa., plant of the American Viscose Corp. are included. E. D. Klug

Fiber Properties in Tire Cord

Relationships of cotton fiber properties to strength and elongation of tire cord. Robert W. Webb and Howard B. Richardson, Cotton and Fiber Branch, Office of Marketing Services, U.S.D.A. and W.F.A., June, 1945. 46 pp. 26 figs. (Processed)

This report completes the second segment of a broad study on the relationships of cotton-fiber properties to the quality of manufactured products. Comprehensive studies have been made of the relationships and contributions of a number of cotton-fiber properties, separately and in various combinations, to the strength of 23/5/3 carded tire cord, to the percentage of elongation of such tire cord at the 10-lb. load, and to the percentage of cord elongation at its point of rupture. The findings represent 754 case-historied American Upland cottons covering a wide range of growth conditions and fiber properties.

The fiber properties have been found to rank in order of importance to tire-cord strength, as follows: fiber strength, coefficient of length variability, grade of cotton, fiber fineness, percentage of mature fibers, and upper quartile length. The contribution of the percentage of mature fibers and of upper quartile length to tire-cord strength is statistically insignificant. When an increase in tire-cord strength accompanies an increase in fiber length, as frequently is the case, it is due to an associated increase in fiber fineness or fiber strength, or both, rather than to the increase in fiber length itself.

As a practical matter, therefore, fiber length as determined by laboratory methods or staple length as designated by the classer provides a useful basis for the selection of cottons for tire cord and other uses because other fiber properties, such as fiber fineness and tensile strength, are generally associated with fiber length. Staple-length designations assume importance, moreover, in that they serve as an essential basis for the selection of cottons to meet the requirements of specific roll settings and drafts in manufacturing organizations.

A coefficient of multiple linear correlation of 0.920 has been found for the relationship existing between the strength of the tire cord and the six collective fiber properties. This is relatively high, 84.6% of the total variance in the tire-cord strength of these cottons being accounted for by the fiber properties considered.

Twenty-three regression equations have been developed from which estimated strength of 23/5/3 tire cord may be predicted on the basis of one or more fiber properties. The precision of each of these equations is reported, together with the coefficients of correlation and determination. Essentially as high a correlation has been found for the relationship between the tire-cord strength and the 4 collective fiber properties of strength, fineness, coefficient of length variability, and grade as was obtained with the 6 fiber properties. With other combinations of fiber properties, the coefficients of correlation are less and the amount of explainable variance in tire-cord strength is reduced. The results of simple correlation analyses indicate

relatively low or poor correlation between any one of the fiber properties and tire-cord strength. The fiber properties, however, vary considerably in this particular.

A coefficient of multiple linear correlation of 0.679 has been found for the relationship between the percentage of tire-cord elongation at the 10-lb. load and the 6 fiber properties considered. This is relatively low, only 46% of the total variance in this tire-cord elongation being explained by the fiber properties. About as high a correlation has been found for the relationship between the tire-cord elongation at the 10-lb. load and the 2 fiber properties of fineness and strength, as was obtained with the 6 fiber properties.

Only 2 of the fiber properties have been found to affect significantly tire-cord elongation at the 10-lb. load. Ranked in order of importance, they are fiber strength and fiber fineness. Four fiber properties significantly affect tire-cord elongation at the point of rupture. Listed in order of importance, they are fiber strength, fiber fineness, coefficient of length variability, and grade.

Each increase of 1% in tire-cord elongation at the 10-lb. load is associated with a reduction of 0.58 lb. in tire-cord strength; and each increase of 1% in the tire-cord elongation at the point of rupture is associated with an increase of only 0.08 lb. in tire-cord strength.

In the light of the findings obtained, it would appear that tire-cord elongation is due either to some one or more fiber properties not considered in these analyses—such as fiber elongation and elasticity—or else that elongation is more a function of the construction of tire cord than it is of fiber properties.

A small but significant negative relationship occurred between the strength of this tire cord and the percentage of elongation at the 10-lb. load. An insignificant positive relationship, however, appeared between tire-cord strength and elongation at the point of rupture. A fairly high positive relationship exists between the two elongation measures, the coefficient of simple correlation being +0.871.

A relatively high positive correlation exists between tire-cord strength and the skein strength of 23s single carded yarn spun with optimum twist multipliers. The coefficient of correlation is +0.897, and 80% of the variance in the tire-cord strength is explained by yarn strength. An equation is given whereby the strength of 23/5/3 tire cord may be predicted from a knowledge of the skein strength of 23s singles yarn.

In considering the equations, statistical values, and conclusions presented in this paper, it should be understood that they refer only to one construction of tire cord—namely, 23/5/3, and only to American Upland cottons. What the results would be from similar analyses with other constructions of tire cord, of which there are many varied and specialized types, or with other growths of cotton, is problematical.

[Cf. TEXTILE RESEARCH JOURNAL **15**: 167 (Apr. 1945).] Author

Physical Properties of Tire Cords

The effects of temperature and humidity on the physical properties of tire cords. J. H. Dillon and I. B. Prettyman. *J. Applied Phys.* **16**, 159–72 (Mar. 1945).

Apparatus by means of which tire cords may be conditioned and tested at elevated humidities (1.6–65% R. H.) and temperatures (20–165°C) is described. The apparatus consists of a portable conditioning unit which is used with a standard tensile testing machine. Equipment for measuring creep of tire cords under dead load at elevated temperatures is also described. Five representative types of tire cord were employed in the experiments: medium-stretch cotton, low-stretch cotton, viscose rayon, Fortisan, and nylon. Tenacity, "10-pound stretch," and ultimate stretch are studied as functions of relative humidity, temperature, and moisture regain. It is shown that the tensile properties are best represented as functions of temperature at constant regain. The tenacity of viscose rayon cords decreases with increasing temperature at constant regain in the range of regains 0–5%. The tenacity of the medium-stretch cotton cards at constant regain falls off with increasing temperature in the range of 20–100°C and then changes very little up to 165°C. That of the low-stretch cotton cords, however, decreases in a manner similar to that found for rayon. The Fortisan cords show a decrease of tenacity in the range 20–100°C and then a slight increase for higher temperatures. The cotton, rayon, and Fortisan cords give nearly linear creep curves (elongation *vs.* log time) in the range of creep times 0.002 to 20 hours. The creep curves for nylon show a tendency to increase in slope at extended creep times. The creep data are analyzed in terms of two arbitrarily defined indices, "initial compliance" and "weighted creep." Both the tensile and creep characteristics are discussed from the viewpoint of current theories of structure and also in the light of their relations to serviceability in tires. Author

Weaving Waste

Waste in cotton weaving. John H. Strong. *Text. Mercury and Argus* **112**, 107, 109, 112, 167–9 (Jan. 26, 1945, and Feb. 9, 1945).

The real loss from waste is of three kinds: price of the raw material, cost of manufacturing to the point where waste is made, and loss of manufacturing profit on the faulty fabric, which has to be sold at a reduced rate. Suggestions are given for the elimination of waste in spinning, winding, warping, sizing, collection of waste, weaving, and in details of personnel cooperation.

E. G. Martin

Integral Yarn Numbering System

Another yarn numbering system offered. Squire Blackshaw. *Rayon Text. Mo.* **26**, 277–80 (June 1945).

A complete description of the proposed numbering system for all textiles, called the "Integral" system. The basis is weight per unit length, in which the weight in pounds on one "wrap" (700,000

yds.) or the weight in grains of one "wraplet" (100 yds.) is the number of yarn, roving, sliver, or lap, one wrap being equal to 7,000 wraplets. Conversion constants and a table are given. H. J. Burnham

New Fabrics

New fabrics of the future. A. C. Robert. *Textile Age* **9**, 68, 70, 72, 74–5 (June 1945).

A condensation of previous articles. The use of nylon, palconia (redwood fiber), ramie, and aluminum fiber in fabrics not being woven commercially at present is discussed. The type of fabrics for which these fibers in staple form might be suitable is discussed, particular emphasis being placed on blends with cotton and wool. H. J. Burnham

Weaving Nylon

Some essential aids to the weaving of nylon fabrics. J. W. Hutchinson. *Silk and Rayon* **19**, 206–7 (Feb. 1945).

For nylon weaving the ordinary make of temples with spiked rings, or roller temples, are not suitable. Two of the latest types are shown. A description of the "Crowgroove" temple is given. The major difference between an ordinary ringed temple and the new "Crowgroove" is in the structure of the cap on the inside. The Lupton Temple has no rings and is as wide as the cloth being woven. Also illustrated is a method for winding the cloth, the main feature of which is the chain-and-sprocket drive between the shaft of the take-up roll and cloth beam, an improvement over the friction-driven cloth beam.

A. L. Merrifield

Wear Resistance

Wear resistance of apparel textiles: A literature survey. Harry S. Hall, Ernest R. Kaswell. TEXTILE RESEARCH JOURNAL **15**, 178–89 (May, 1945).

A survey of abstracts and articles in the periodical literature, dealing with the subjects of wear, resistance to wear, and factors affecting wear, emphasis being placed upon wear by abrasion. Included are short descriptions of machines and methods for measuring certain wear factors as found in service or imitated in the laboratory. Several of the articles are reports on conferences. J.

BLEACHING: DYEING: FINISHING

★

Esterized Dyes

Textile dyes which are applied by saponification. J. Wakelin. *Silk and Rayon* **19**, 202, 205 (Feb. 1945).

Some of the devices introduced to make dyes easy to apply, yet fast and permanent on the fiber, are not generally known. Some of the insoluble azo and anthraquinone colors may be solubilized by esterification and regenerated to insoluble dyes by saponification. Dyeing of fabrics with "acylated" dyes usually involves padding or impregnation followed by treatment with an alkaline solution. The esterified azo dyes may be incorporated in the spinning solution of synthetic fibers and regenerated during spinning or developed by treatment with dilute ammonia solution. This also offers a method by which plastics may be colored and the dye developed at any convenient stage during fabrication. A. L. Merrifield

Dyeing Damaged Wool

The level dyeing of damaged wool in raw stock dyeing. J. O'Day. *Am. Dyestuff Reptr.* **34**, 157–8 (Apr. 9, 1945).

A wool raw stock mixture which contained (a) pulled wool from which the lime had been incompletely cleansed, (b) Australian wool damaged by mildew and (c) damaged by sunlight, presented a difficult dyeing problem; covert cloth produced from the dyed mixture showed numerous white specks and light and dark streaks. Satisfactory dyeing was finally obtained, however, by selecting certain dyestuffs (a list of which is given), by the use of a colloidal protective agent to prevent packing and channeling during pressure dyeing, and by completely exhausting the color with formic acid before adding chrome. K. S. Campbell

Stability of Hypochlorite

Effect of certain vat dyes on the stability of NaOCl solutions. K. S. Bhujang, S. H. Mhatre, and G. M. Nabar. *Current Sci.* 13, 281–2 (1944) (through *Chem. Abstr.* **39**, 2407⁴, June 10, 1945).

Cotton dyed with Ciba Blue 2B was partially bleached in NaOCl solution containing 2.5 g. available Cl per l. After 10 min. the cotton was removed. This solution, buffered at pH 7, lost 4% of its strength in the next 20 min., while a blank lost 1%. The blank and the used solution had the same rates of decomposition after 2 hrs. The behavior is comparable in both acid and alkali solutions. The rate of decomposition depends on pH and on the concentration of dyes: the oxidation products from the dye catalyze hypochlorite decomposition.

Cloth Steaming

Steam processing scours cotton continuously. P. J. Ariente. *Textile World* **95**, 94–5 (July 1945).

A process developed by the Matheison Alkali Works and used at the Sayles Finishing Plants, Inc., is described which handles cotton cloth in open widths, passing it through a padder with a solution containing 6.5% caustic soda, 0.5% synthetic detergent, 0.1% penetrant, and 0.25% Textone at 100 yds. per min., thence through the steam chamber in loose folds on a conveyor traveling 2 feet per minute. H. J. Burnham

Shrinkage Control

Shrinkage control of wool. A. D. Nute. *Am. Dyestuff Reptr.* **34**, 167–9 (Apr. 23, 1945).

Twelve processes for controlling the shrinkage of wool are briefly reviewed. Details of the application of methylated methylol melamine resin (trademarked "Lanaset") to

wool are described; points mentioned are: (1) about 10% of this resin based on cloth weight is necessary for maximum shrinkage control, (2) the resin may be applied either to wet or dry wool fabric, (3) a strong bath with low pickup is preferred, (4) the oil content of the wool fiber should be less than one-half of one percent, (5) the process does not change the fiber chemically, and leaves the material with good hand, air porosity and draping qualities. K. S. Campbell

Water Repellency

The water repellency of textile fabrics. H. Wakeham, W. B. Strickland, and E. L. Skau. *Am. Dyestuff Reptr.* **34**, 178–82 (Apr. 23, 1945).

The resistance of a fabric to penetration by water depends not only upon the twist of the yarn and the closeness of the weave, but also on whether the surface is easy or hard to wet. Wettability depends upon the chemical and physical properties of the fibers and those of the substances with which the fibers are contaminated or with which the yarns or fabrics are finished. From a consideration of the physico-chemical principles of wetting, the contact angle between the water and the fabric is found to be of great significance with regard to water-repellent behavior of the fabric. The tensiometric test for determining contact angle permits an evaluation of the fabric finish independently of the weave construction. The contact angles determined on a number of samples correlated well with the usual spray-test ratings and with hydrostatic pressure and Gurley Densometer air permeability values. Author

Effect of Wet Finishing on Nylon

The effect of wet finishing on certain physical properties of nylon. Northern New England Section, AATCC. *Am. Dyestuff Reptr.* **34**, 146–56 (Apr. 9, 1945).

The effect of time and temperature of immersion (at various intervals between 15 seconds and 30 minutes and between 35° and 212° F) on several physical properties of nylon is described. Immersion temperatures up to 250° F do not affect adversely either the static or the impact strength. The energy-absorbing characteristics of nylon can be improved by proper time and temperature conditions during wet processing. After nylon has been steamed subsequent heat treatments below the boil affect neither the strength nor percent elongation; resilience tests show that steaming at 250° F produces superior compression resistance and recovery properties in knitted nylon fleece; abrasion resistance of nylon singles was likewise improved. The ultimate regain of nylon was increased by previously wetting out in water and allowing to condition from the wet side even if then repeatedly bone-dried and conditioned from the dry side; in practice such an increase may amount to as much as 28.5% above the normal regain. In order to ensure satisfactory dyeing and to eliminate possible non-uniformity, the history of nylon pieces or yarns must be known or high-temperature wet treatment must be given. Twenty-eight graphs. K. S. Campbell

MISCELLANEOUS

★

Machine-Picked Cotton

Machine-picked cotton shows steady improvement. E. H. Helliwell. *Textile World* **95**, 123, 125 (July 1945).

A report on tests of the upland cotton-picker during the 1944 picking at Springfield, S. C. Part of the loss in grade, one to two grades, is regained at the gin by proper cleaning and drying methods. In comparative tests on 20s to 60s yarns, yarn appearance dropped from B+ to B and yarn strength dropped 0.7% in machine-picked over hand-picked cotton. It is said that the present average cost for picking cotton by hand is $40 per bale, whereas it can be machine-picked for $5 to $6 per bale. H. J. Burnham

Committee Hearings on Cotton

Cotton. Hearings before the Subcommittee of the Committee on Agriculture, House of Representatives, December 4 to 9, 1944. Washington, U. S. Government Printing Office, 1945. 850 pages.

In this volume is presented the testimony of some 58 witnesses before the Pace Subcommittee, with their policy recommendations, related statements, and views respecting present and post-war programs for cotton. As indicated in a 33-page summary at the front of the book, there was general agreement on continued and expanded research to strengthen cotton's position as a competitor of synthetics, for a continued and expanded soil conservation program, for a reduction in cost of production, and on the necessity for continued support of cotton prices during the transition to any ultimate post-war program. There was considerable diversity of opinion regarding acreage and production control, mechanization, price policy, tariffs, export subsidy, and other points. Several recent studies on the economics of cotton are reprinted in the appendix.

R. B. Evans

Trends in Cotton Demand

Recent trends in the demand for American cotton. Cyril O'Donnell. Chicago, University of Chicago Press, January, 1945. 53 pages and appendix. Price, $1.00. (A supplement to the *Journal of Business of the University of Chicago* **18**, No. 1, Part 2.)

This study tests the statistical relationship developed by the late Professor Henry Schultz in his work *The Theory and Measurement of Demand* (Chicago, 1938), regarding factors that affected the price of cotton during 1920–32. On the basis of the period 1920–38, it is found that variations in domestic supply accounted statistically for 79.49% of the variation in price as compared with Schultz' 71.42%; world business conditions, 6.2% instead of 13%; and foreign supply, zero in-

stead of 8.8%. The study also investigates Schultz' finding that the per capita consumption of cotton in the United States is declining and that the demand curve for cotton is growing more inelastic. Consumption of cotton in consumer goods is said to have been adversely affected by competition of synthetic fibers in design and price. In industrial uses of cotton, the business cycle, natural growth in the total population, and military requirements are held to be the three fundamental factors responsible for variation in consumption. Efforts of the Federal Government to increase consumption of cotton by various means are evaluated. According to the author, Federal intervention in the cotton economy reacted to the advantage of foreign producers, but at the same time kept "surplus" stocks of cotton out of the hands of the enemy. A middle-of-the-road government cotton policy is advocated as the best course in the present state of the political and economic development of the world. It is held that world consumption of American cotton will be high during the post-war period if peace and access to world markets are assured, and as additional areas of the world are gradually industrialized. R. B. Evans

Cotton Industry of India

The Indian cotton textile industry (1880–1939). V. Ramakrishna Rao. *Indian Text. J.* **55**, 305–7 (Feb. 1945).

The growth and development of the Indian cotton textile industry are studied in the light of various influencing factors. The industry dates back to 1818, when the first mill was started in Calcutta, but complete statistics were not reported until 1879–80. The industry employs directly no less than 450,000 persons and perhaps as many indirectly in subsidiary industries. The value of total cotton exports on private account is about 25% of all the exports from India. Ruby K. Worner

Fluorescent Lamps

Fluorescent-lamp problems challenge the electro-chemist. Richard G. Slauer. *Trans. Electrochem. Soc.* **87**, 7 pp. (preprint) (1945) (through *Chem. Abstr.* **39**, 2258[5], June 10, 1945).

In spite of the rapid growth and widespread acceptance of the fluorescent lamp, it still presents important problems. There is no fluorescent lamp that reproduces daylight perfectly. No lamp is entirely free from Hg arc rays that pass through the phosphor. Hg may not be the best means of generating ultraviolet radiation. The fluorescent lamp is an efficient light source within a very narrow temperature range of the surrounding atmosphere (30° to 50°). New phosphors are desirable. Better methods and control in preparing and compounding the phosphors are likewise needed. Is it possible to use a plastic tube in place of the glass tube? Are BaO and SrO the best electron emitters for the fluorescent lamp?

Nylon Polyamides

Nylon polyamides: Their chemical and industrial development. Howard H. Irvin. *Chem. and Met. Eng.* **52**, 94–7 (May 1945).

A review. 42 references.

E. D. Klug

Sericulture

New strain of mulberry tree in America helps development of sericulture. Anon. *Indian Text. J.* **55**, 341 (Feb. 1945) (from *Foreign Commerce Monthly*).

The new strain of mulberry tree, developed by Dr. Vartan K. Osigian, and named *Morera Osigian*, is said to produce a crop of leaves in 6 mos. —leaves which are more tender, have more sap, and are 6 to 8 times as large as the usual leaf. Some 2,500,000 trees of the new strain are growing in Venezuela.

Ruby K. Worner

Silk Production

The story of silk from moth to fabric. F. H. Clayton. *Silk and Rayon* **19**, 183, 186, 190 (Feb. 1945).

A brief history is given of the expansion of sericulture from China to Europe. About 85% of the silk employed by the trade is produced by the small silkworm *Bombyx mori*; larger silkworms produce coarser and less valuable fibers. A single moth lays up to 600 eggs; approximately 3,500, 1 oz. of eggs, produce 110 lbs. of cocoons, or about 9 lbs. of reeled silk. About 25% of the 3,000 yards in a cocoon is first-quality fiber which is processed as continuous filament; the waste yarn is processed in a manner similar to the method used for spinning worsted. A. L. Merrifield

Slater Memorial Laboratory

Samuel Slater Memorial Textile Research Laboratory. Edward R. Schwarz. TEXTILE RESEARCH JOURNAL **15**, 33–6 (Feb. 1945).

Some of the equipment in use at the Slater Memorial Laboratory in the Textile Division of the Massachusetts Institute of Technology is described. J.

Organized Research

Organized and unorganized research. Wanda K. Farr. *J. Chem. Ed.* **22**, 140–3 (Mar. 1945).

An address presented at the Women Chemists' Dinner, American Chemical Society, Cleveland, Ohio, April 4, 1944. Ruby K. Worner

Country Homes for Research Laboratories

Country homes for research laboratories. W. B. Foulk. TEXTILE RESEARCH JOURNAL **15**, 190–3 (May 1945).

The conversion of the Textile Research Institute property at Princeton N. J., into a research laboratory is described. J.

The Age of Textiles

The age of textiles. Memphis, National Cotton Council of America, May, 1945. 15 pages.

Information regarding origin, manufacture, properties, prices, and uses

of the various synthetic fibers is presented in non-technical language.
R. B. Evans

Consumer Demand for Textiles

Consumer demand and purchases of 75 clothing and textile items, year 1943 and first quarter 1944. *Facts for Industry*, series 15-1-1. Washington, War Production Board, June 2, 1945. 73 pages.

On the basis of interviews with a sample of 4,732 representative families in the United States, estimates are made of consumer purchases and shortages of 75 clothing items. Data on clothing purchasing habits at different income levels for farm and non-farm families are presented. A list is given of 25 clothing and textile items most frequently received as gifts. R. B. Evans

Economic Issues in Textiles

Economic issues in textiles—a challenge to research. Hiram S. Davis. Philadelphia, Industrial Research Department, Wharton School of Finance and Commerce, University of Pennsylvania, May, 1945. 32 pages. Price, $0.50.

The author cites the need for research to assist the country in arriving at wise decisions on nine basic economic issues affecting post-war textiles. These issues involve prices of raw material, wage rates, capital returns, production costs, foreign trade, domestic markets, distribution costs, industry organization, and fluctuations in textile business. Possibilities and implications of various policies regarding each issue are discussed and areas where research is needed are indicated. It is mentioned that there has been a lack of evidence of significant permanent progress in getting out more textiles per worker during the war, and the need for research to find means of increasing the output per man-hour as the only permanent support for a higher actual return to wage earners, is emphasized. Possibilities of lowering production costs by installment of new equipment, "round the clock" work, and greater standardization of product are discussed. Detailed, product-by-product market studies are cited as being needed to anticipate post-war readjustments. In conclusion, the author states that the goal of the textile industry, or any industry, should be maximum economic progress with minimum economic instability.
R. B. Evans

Textile Books

Textile books: the urgent needs. J. C. Withers. *J. Text. Inst.* **36**, P51–8 (May 1945).

In a paper delivered to the Lancashire Section of the Textile Institute (British), the author discusses the existing situation in regard to books on textile subjects. It is pointed out that there have been published comparatively few comprehensive treatises in recent years. The Textile Institute, for example, has most of the live books in English, but can accommodate them all in one small room. The Shirley Institute has for 24 years pursued the policy of acquiring every book on the cotton, rayon and silk industries that could be secured, whether old or new, and in whatever language, and yet the shelf space now occupied by books—apart from bound volumes of periodicals—is only some 160 feet. By contrast with the magnitude of the industries, the number of technologists engaged in them, and the very wide range of topics that might have been written up in book form, textile literature is meager indeed. Some of the existing books are mentioned and discussed. Suggestions are given for subjects that should be brought out in book or monograph form. J.

Textile Production

Trends in textiles and clothing. Loughlin F. McHugh. *Survey of Current Business* **25**, 15–20 (Apr. 1945).

Production of clothing to meet civilian needs has been well maintained during the war, with exceptions in certain items. Consumer expenditures for clothing have doubled since 1939, as a result of such factors as durable consumer goods disappearing from the market and 42% rise in clothing prices. Most of the recent sharp increase in clothing prices has been due not to actual ceiling-price increases but to a shift to higher-priced lines. Total production of cotton fabrics has continued to decline since a peak in 1942, but production of rayon and woolen and worsted fabrics has been well maintained. Failure to increase production of textiles is currently due to declining employment rather than to lack of materials, profit incentive, or capacity. Methods and objectives of the government's textile production and distribution program are analyzed.
R. B. Evans

Small Business Growth

The growth factor in small business. Earl P. Stevenson. TEXTILE RESEARCH JOURNAL **15**, 7–9 (Jan. 1945).

The question, how can small business serve itself and be served by industrial research and development, is discussed. J.

Personnel Department

Nashua induction program aids returning veterans. Guy W. Swallow, Cecil Barnes, and Anne Willard. *Textile World* **95**, 102–3 (July 1945)

A description of the successful attempt by the Nashua Mfg. Co., Nashua, N. H., to reduce labor turnover. Particular attention is paid to job placement, orientation, and follow-up interviews. It is claimed that the labor turnover rate for six-week periods has been reduced from 39% to 18%. The company's policy in handling returning veterans is outlined. H. J. Burnham

Pattern for Industry

Mather Lecture: pattern for industry. C. J. T. Cronshaw. *J. Text. Inst.* **36**, P65–76 (June 1945).

In the 1945 Mather Lecture, the lecturer dwells on the importance of history as forming a basis for deductions as to the future. He traces the trend of events in history and draws a parallel in industry. He

shows us specifically that the effective unit has tended to increase over the years. The pattern for research is given as a trinity of resolve and endeavor—research, production, and selling, not separate but doubled, twisted, and interwoven into a flexible fabric. The three components are discussed in detail. J.

The Grex System

A universal yarn count system. Anon. *Text. Mfr.* **71** (June 1945).

A report on a conference of the Textile Institute (British), at which it was recommended that a universal yarn numbering system be adopted. The Grex system would not replace any present system but would be used as a common alternative or secondary system. Summaries of 8 papers presented to the conference are given, and are informative in that they express the reaction of the various sections of the textile trade to the proposed system. The sections are: cotton yarns, doubled and fancy yarns, worsted yarn, scottish woolens, rayon yarns (2 papers), spun silk, and cordage and twines. H. J. Burnham

PATENT REFERENCES

★

Knitting Machines

Knitting and knitting machine. Ralph N. Toone and Thomas L. Allen (to B. Toone, Eng.). U. S. 2,377,729 (June 5, 1945).

The object of the invention is to eliminate loose ends of threads on fabrics produced on independent needle machines. The purpose is accomplished by feeding an additional thread and, while this thread is still running to and being knitted by the needles, severing it so that all the thread extending from the point of severance to the needles is knitted in, and re-introducing the same or a different thread with a free end extending beyond the point of introduction, and of such length that the needles in descending to knit absorb or draw and knit it.

Knitting machine. Isaac H. C. Green and Eugene St. Pierre (to Hemphill Co.). U. S. 2,381,275 (Aug. 7, 1945).

An improvement in machines for the production of split-foot hosiery is described for use in a Banner type circular, independent needle, knitting machine. It is stated, however, that it may be adapted for other machines having generally similar characteristics.

Improvement in Cotton's Patent or other straight bar knitting machines. William Gordon Macdonald and William Arthur Cooper (to William Cotton Limited). U. S. 2,381,072 (Aug. 7, 1945).

Improved slur cams for use on straight bar knitting machines. Frank G. Weisbecker. U. S. 2,381,376 (Aug. 7, 1945).

Improved timing and controlling mechanisms for circular knitting machines. Thomas Charles Bromley and Arthur Shortland (to Mellor Bromley & Co., Ltd.). U. S. 2,381,641 (Aug. 7, 1945).

Knitting Machine Parts

New and improved parts for knitting machines. De Hart G. Scrantom (to Western Electric Co., Inc.). U. S. 2,381,370 (Aug. 7, 1945).

An improved jack for holding the nib of the knitting needles is described.

Looms

Lay motion for looms. Robert J. Bartholomew (to Fletcher Works, Inc.). U. S. 2,381,028 (Aug. 7, 1945).

The principal object is to effect a material reduction in the throw of the cranks by which the lay of a loom is oscillated or reciprocated and, hence, to increase the hourly production of the loom. It applies particularly to narrow fabric looms. By use of a novel form of reed and operating mechanism, the throw of the lay-operating cranks may be reduced to approximately one and one-quarter inches with a corresponding reduction in the travel of the lay.

Electropneumatic Loom

Electropneumatic loom. Eneas G. Mascarenhas. U. S. 2,377,800 (June 5, 1945).

The invention has for its principal object the provision of a loom characterized by simplicity in construction and operation; inherently lighter than looms of commensurate cloth width; and comparatively free from inertia vibration of massive parts such as the lay. Power is applied directly to the principal motions by fluid-pressure motors which are operated in properly timed relation.

Loom Shuttles

Loom shuttle. Harold E. Goff and Walter F. Daboll (to Williams Mfg. Co.). U. S. 2,377,079 (May 29, 1945).

A self-threading shuttle of improved construction by which ballooning and resultant breaking of weft threads may be substantially avoided. An anti-ballooning plate and associated funnel are provided, the plate being positioned close to the tip of the bobbin and the funnel extending close to the threading eye in the shuttle.

Shuttle for automatic looms. Carl D. Brown (to Draper Corp.). U. S. 2,381,333 (Aug. 7, 1945).

It has previously been proposed to reinforce the wood adjacent to the side delivery eye by inserting pegs of wood, metal, or other suitable material. These pegs have the defect of loosening and becoming ineffective in preventing splitting or breaking of the wood. With the present invention, the peg is inserted into the body of the block in a position where it will be engaged and locked into position by the clamping means. In the illustrated construction, two vulcanized fiber pins are used, both pins being cut away to a certain extent when the front wall is counter-bored to receive the head of the clamping

bolt. Thus, each pin is engaged by the head of the bolt and is prevented from loosening and pulling out of the shuttle.

Shuttle for narrow fabric looms. John Kyle Dudley. U. S. 2,381,042 (Aug. 7, 1945).

The shuttle has been designed to carry a bobbin of increased size which can be wound on a conventional automatic winding machine. The center of gravity of the loaded shuttle has been moved closer toward the vertical center of the guide or track in which the shuttle reciprocates in order to reduce friction and wear, and permit of increasing speed of the loom.

Loom Attachment

Center filling fork loom attachment. Walter B. Gallant, Jr. (to Newmarket Mfg. Co.). U. S. 2,377,223 (May 29, 1945).

The object of the invention which applies to automatic looms with center fork filling feeler is to indicate a broken pick or filling thread and to actuate the mechanism to stop the loom. The object is to put the center fork filling feeler out of action only during that particular pick and to allow it to resume operation immediately thereafter.

Heddle Frame

Heddle frame. George R. Plott. U. S. 2,381,308 (Aug. 7, 1945).

This invention relates to a means for mounting the heddle bars in the heddle frame so that they can be quickly inserted in place and quickly removed from the frame.

Stop Motion

Stop motion for textile machines. Herman T. Overbey (to J. F. Martin and H. P. Taylor). U. S. 2,381,683 and 2,381,684 (Aug. 7, 1945).

The present invention relates to a stop motion mechanism for warp-wind spinning and twisting machines to stop the machine after a predetermined yardage of thread or yarn has been wound on the bobbin.

Staple Fiber Cutter

Apparatus for cutting continuous filaments into discontinuous lengths. Dan B. Wicker and Charles W. Cox (to American Viscose Corp.). U. S. 2,381,240 (Aug. 7, 1945).

Tow Guide

Tow guide. Seddon C. Nelson (to American Viscose Corp.). U. S. 2,377,173 (May 29, 1945).

The invention relates to guides for filamentary material and is designed especially for guides for controlling the movement and shape of bundles of filamentary material during liquid treatment. The guide permits a plurality of bundles to pass through a liquid in a flattened or spread-out condition, so that all the bundles and all parts thereof are equally available to the treating liquid and uniformly conditioned by the same.

Unwinding Yarn

Unwinding yarn. Paul W. Markwood (to American Enka Corp.). U. S. 2,377,799 (June 5, 1945).

An apparatus for unwinding yarn from a package which overcomes some of the previous difficulties in this operation and permits an uninterrupted unwinding operation and results in a knot-free thread.

Electric Weft Detector

Electric weft detector for looms. Oscar V. Payne (to Crompton & Knowles). U. S. 2,377,102 (May 29, 1945).

An improved electric weft detector reduces the tendency to abrade fine weft, which has been a defect in previous detectors, particularly when the contacting part of the detector strikes only a single strand of thread. In this invention the general object is to provide electric means by which a very brief indication of exhaustion by the detector can be utilized to stop the loom for a change in its operation.

Coating Machine

Machine for coating textile fabrics. Joseph Lloyd (to J. Mandleberg & Co., Ltd., Eng.). U. S. 2,377,637 (June 5, 1945).

A method for application of rubber, cellulose derivative, and other coatings to fabrics provides means for coating the fabrics uniformly right up to and including the edges so that fabrics without selvages, such as tubular (circular) fabrics, can be given any desired coating without leaving uncoated strips and without necessitating, in the case of plain or non-tubular fabrics, any trimming of the edges. The invention also has to do with the production of laminated fabrics in which the plies are connected with an adhesive.

Insulating Fabrics

Thermal insulation material made from fibrous substances. Walter Garner (to Lister and Company, Ltd.). U. S. 2,381,214 (Aug. 7, 1945).

The invention relates to improvements in thermal insulation materials made from fibrous substances and useful in a wide variety of applications such as clothing, sleeping bags, and coverings or linings for buildings, vehicles, etc., the primary object being to permit fabric constructions which contain in their interior a layer of fairly still air, which can be easily woven and which are relatively strong. Two distinct textile fabrics, preferably light in weight, are tied together or connected by a pile of closely packed or lightly twisted fibers. Or the connecting elements may consist of yarns.

Liquid Treatment for Filaments

Liquid treatment of filaments. Richard W. Stanley and Henry J. McDermott (to American Viscose Corp.). U. S. 2,377,655 (June 5, 1945).

Method for treating single strand or continuous filamentary bundle with liquids consists of running the strand upward at an angle to the vertical and applying the liquid by means of a nozzle which directs the jet along the filament. Method may be used for application of liquids in treatment of yarns.

Pigment Composition

Pigmenting composition. Paul L. Meunier (to du Pont). U. S. 2,377,709 (June 5, 1945).

A pigmenting composition for textile fabric composed of a water-insoluble organic pigment, water, a heat-convertible starch derivative, and a capillary-active agent. The invention has for its object to provide a method for the dispersion of water-insoluble pigments in binders of starch origin which deposit water-resistant films upon drying and (1) to accomplish this dispersion without causing undesirable viscosity variations in the starch derivative vehicle; (2) to effect the dispersion without introducing large quantities of auxiliary agents, which require removal by washing; and (3) to effect and to maintain the dispersion of pigments in the starch derivative vehicles by means of a reagent which is universally effective with a wide variety of pigments and which is not readily affected by variations in the pH of the system. To the commercial color paste in lieu of, or in addition to, the customary dispersing agents, a member of the group consisting of the lignin-sulfonic acids and their water-soluble salts is added.

Elimination of Static

Antistatic treatment of vinyl resin textiles. Benjamin G. Wilkes and Walter A. Denison (to Carbide and Carbon Chemicals Corp.). U. S. 2,381,020 (Aug. 7, 1945).

The object of the invention is to eliminate the tendency of textiles made from, or containing, water-insoluble vinyl resins to accumulate charges of static electricity either during their production, or in connection with the usual finishing operations. It is based principally upon the discovery that the accumulation of a charge of static electricity on the surfaces of fibers, films, yarns and fabrics containing these resins may be prevented or retarded by treatment, preferably after the usual scouring and rinsing operations, with one or more highly basic, water-dispersible polyalkylene imines having average molecular weights of at least 300, and particularly with such higher polymers of ethylene imine.

Improvement of Tenacity

Textile material. Arthur Lyem (to Celanese Corp. of America). U. S. 2,377,434 (June 5, 1945).

A treatment for textile yarns, filaments, fabrics, and the like which have a basis of an organic derivative of cellulose is described. Such materials are subjected in a continuous process the action of acetaldehyde, which causes the material to shrink. As a result of this treatment the tenacity, and particularly the elongation characteristics of the material are enhanced. The apparatus used is described.

Textile Treatments

Treatment of textile materials. Ira L. Griffin, Dave E. Truax, and Norman H. Nuttall (to Stein, Hall & Co., Inc.). U. S. 2,381,587 (Aug. 7, 1945).

One of the objects of the invention is the treatment of textile fibers to give greater permanency to films on the fibers and fabrics without the necessity of employing a synthetic resin, although such a resin may be employed if desired. It is said to impart water resistance by employing compositions, the major preparation of which is comprised of relatively inexpensive materials. For example, amylaceous materials such as starches, dextrines or other starch degeneration products, including modified starches, and natural gums, such as locust bean gum. It is said to be especially useful in connection with dyeing and printing of textiles.

Glass Fiber Window Shade

Coated glass fiber window shade. Charles S. Hyatt and Thomas J. Kerr (to Columbus Coated Fabrics Corp.). U. S. 2,381,542 (Aug. 7, 1945).

The object of the invention is to provide a substantially transparent coated fabric shade cloth which is highly resistant to deterioration by the action of sunlight, water, heat and cold, and which is economical to produce, and durable. It is said to overcome the objectionable features in the usual organic fiber base cloth due to the fact that in a transparent shade the actinic rays of the sun are not absorbed in the coating, which leaves the fiber base material subject to disintegration. Furthermore, with organic fibers it is usually necessary to bleach the cloth before applying the coating, and traces of the agents used remaining in the cloth result in early disintegration of the fiber base as well as attack the coating. In this invention the use of glass cloth eliminates the necessity for bleaching or chemical treatment of the fiber, and substances used to chemically clean the glass are readily removed. Window shade cloth made according to this invention preferably comprises woven glass fabric to which is applied an adhesive plastic coating. Typical examples of lacquer coatings are given.

Knitted Fabrics

Method of incorporating elastic thread in knitted fabrics. James L. Getaz. U. S. 2,377,489 and 2,377,490 (June 5, 1945).

A method is described which incorporates elastic thread in plain knit hosiery tops in only a portion of each successive course of the knitted fabric, and extends the elastic thread from one course to the other without any courses intervening.

Non-Woven Fabrics

Reinforced textile fabric and process of making. George K. Ripley (to Troy Blanket Mills). U. S. 2,381,184 (Aug. 7, 1945).

The invention has to do with a needling process for constructing a textile fabric by which a batt of textile fibers, delivered from a carding machine, is folded back and forth on itself with a plurality of reinforcing threads which run parallel with the side edges of the batt or sheet. Preferably the fabric is passed through a needling machine to fasten it more firmly together but it may be held together by pressure or sizing, or by treating the threads with an adhesive. This is a variation from the well-known process of needling through a foundation layer of woven material.